SOIL FERTILITY MANAGEMENT UNDER DIRECT SEEDED RICE (*Oryza sativa* L.) IN THE ACIDIC SOIL OF NAGALAND

Thesis

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of

DOCTOR OF PHILOSOPHY

in

Soil Science

by

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DECLARATION

I, Seyiekevino Tsükrü, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

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The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN SOIL SCIENCE

This is to certify that the thesis entitled "Soil fertility management under direct seeded rice (*Oryza sativa* L.) in the acidic soil of Nagaland**"** submitted by Seyiekevino Tsükrü, Admission No. Ph - 287/19 Registration No. Ph.D./ACSS/00327 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Soil Science has been examined by the Advisory Board and External examiner on ……………….............

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Date: SEYIEKEVINO TSÜKRÜ

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LIST OF ABBREVIATONS

ANOVA	Analysis of variance
@	At the rate
B:C ratio	Benefit: Cost ratio
C	Carbon
°C	Degree centigrade
Ca^{2+}	Calcium
CD	Critical Difference
CEC	Cation exchange capacity
cm	Centimetre
cmol	Centimol
Cu	Copper
DAS	Days after sowing
df	Degree of freedom
dSm^{-1}	Decisiemens per meter
EC	Electrical conductivity
Ex. Ca^{2+}	Exchangeable calcium
et al.	*et allia* (and others)
Fe	Iron
Fig	Figure

FYM	Farm yard manure
G	Gram
Ha	Hectare
HI	Harvest index
ICAR	Indian Council of Agricultural research
i.e.	Id est (that is)
K	Potassium
kg ha^{-1}	Kilo*gram* per hectare
LR	Lime requirement
M	Metre
m^{-1}	Per metre
m^2	Metre square
M	Molarity
Mg	Magnesium
mg	Milligram
m ha	Million hectares
mt	Million tonnes
MT	Metric tonne
Max.	Maximum
Min.	Minimum

Mn	Manganese
MSS	Mean sum of square
N_2	Dinitrogen
N	Normality
N	Nitrogen
No.	Number
NPK	Nitrogen, phosphorus, potassium
NS	Non-significant
NU	Nagaland University
OC	Organic carbon
OM	Organic matter
%	Percent
P	Phosphorus
pHDA	pH dependent acidity
ppm	Parts per million
PSB	Phosphate solubilising bacteria
q ha^{-1}	Quintal per hectare
RDF	Recommended dose of fertilizer
S	Sulphur
SAS	School of Agricultural Sciences

SEm±	Standard error of mean
SMBC	Soil microbial biomass carbon
SS	Sum of square
t	Tonne
TPA	Total potential acidity
viz.	namely
µg	Microgram
Zn	Zinc

ABSTRACT

The present study entitled "Soil fertility management under direct seeded rice (*Oryza sativa* L.) in the acidic soil of Nagaland' was conducted in the experimental farm of the Department of Soil Science, School of Agricultural Sciences (SAS), Nagaland University, Medziphema, Nagaland during the *kharif* season 2021 and 2022. The experiment was laid out in Randomised Block Design with 15 treatments and replicated thrice. The treatments consist of T_1: Control, T_2: 100% NPK, T_3: 50% NPK, T_4: SSNM (109:30:46 NPK), T_5: 100% NPK + Zn, T_6: 100% NPK + S, T_7: 100% NPK +Zn + S, T_8: 100% NPK +Zn +S + FYM @ 5t ha^{-1}, T_9: 100% NPK + Liming @LR, T_{10}: 50% NPK + Azospirillum, T_{11}: 50% NPK + 50% N-FYM, T_{12}: 50% NPK + 50% N- VC, T_{13}: 50% NPK + 25% N-FYM + 25% N-VC, T_{14}: FYM @ 10 t ha^{-1}, T_{15}: FYM @ 10 t ha^{-1} + Liming @ LR. It was observed that application of T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) had resulted in significantly enhancing the growth and yield attributing parameters as well as the nutrient content and uptake of the rice crop. Treatment T_8 increased grain and straw yield to the extent of 116.79 % and 44.92% over control T_1, respectively from the pooled data. Soil pH recorded a slight raise in lime treated plots while EC and bulk density showed no significant difference. Organic carbon (g kg^{-1}) and TOC (g kg^{-1}) showed highest with T_8 and increased to a tune of 30.24% and 19.40% over control T_1 while CEC in soil was observed to have been increased with the lime treated plots T_{15} which was at par with T_8. Application of T_8 significantly enhanced the available NPK and S while it slightly reduced the exchangeable acidity, exchangeable aluminium, total potential acidity, pH-dependent acidity of the soil. Exchangeable Ca recorded highest with the lime treated plots T_9 and T_{15} but remained non-significant. Micronutrient Zn recorded highest in T_8 with 1.36 mg kg^{-1} and lowest in T_1 with 1.05 mg kg^{-1} whereas for available Fe, Mn and Cu significant difference in the treatments were not observed. Soil microbial biomass carbon and soil basal respiration were also observed highest in treatment T_8. In terms of economic analysis, highest benefit cost ratio was reported in T_7: 100% NPK +Zn + S with 1.64 in 2021 and 1.75 in 2022 followed by T_4: SSNM (109:30:46 NPK with 1.63 in 2021 and 1.71 in 2022. Treatment T_8 reported highest in terms of gross return (₹ ha^{-1}) while net return (₹ ha^{-1}) was highest with in T_7 followed by T_8. B:C ratio values for T_8 was 1.29, 1.37 for the year 2021 and 2022, due to the treatment variations. Comprehensively, the study suggests application of 100% NPK +Zn +S + FYM @ 5t ha^{-1} had proven to enhanced the crop growth, yield characters, nutrient content and uptake predominantly. This treatment also has the potential to maintain the soil health and productivity for sustainable agricultural production system while ensuring an adequate benefit to the farmer in terms of gross and net returns respectively.

Key words: Direct seeded rice, N, P, K, S, Zn, FYM, VC, liming, Azospirillum.

CHAPTER I

INTRODUCTION

INTRODUCTION

Rice crop is the world's third most- produced agricultural crop behind sugarcane and maize. It is cultivated on kharif and rabi seasons in India. Paddy as a Kharif crop is cultivated in autumn season in warmer regions during the monsoon from June to September while as a rabi crop, it is cultivated during winter-spring season from November to March (Infomerics Ratings, 2023). The kharif season is the main rice growing season in India which accounts for about 84 per cent of the country's total rice production. The rabi season is a minor rice growing season and accounts for only 9 per cent of the country's total production. In kharif season, the area sown with rice rose from 38,919 thousand hectares in 2019 to 41,195.80 thousand hectares in 2023, with fluctuations in between. This data provided an insight into the trends and variations in rice crop cultivation in India over the specified years and showed an insight of nation's agricultural landscape and production capacity (Infomerics Economic Research, 2023). Over the past decades, the trend in rice production in India has shown a consistent increase in both kharif and rabi season, with few fluctuations. During 2012-2013 to 2021-2022, kharif rice production increased from 923.59 lakh tonnes to 1052.08 lakh tonnes, while rabi production increased from 128.73 lakh tonnes to 191.60 lakh tonnes, respectively. This growth may be ascribed to various factors including improved agricultural practices, increased use of technology, and government support for the farming sector. Rice production for the year 2023 in kharif is estimated to be around 1100.32 lakh tonnes (Reports from Directorate of Economics and Statistics, Ministry of Agriculture, GoI; Infomerics Economic Research, 2023). Rice crop grown in the acidic soils of Nagaland, which is a staple food with about 86% of the cultivable area in the state under *jhum* and terrace rice cultivation systems (Anonymous, 2017). In India, acid soils are found from extreme south just above 8°N latitude to 36° N latitude in North; these have developed under different climate, vegetation, topography and parent material over a long period of time. Strong and very strongly acidic soils (pH 4.5-5.5) have been reported in the north-eastern, eastern and peninsular regions of India. In India, nearly 92.97 Mha of land suffers from various degrees of soil acidity and impaired soil fertility. It was estimated that about 6.98 Mha area is affected by strongly soil acidity (ICAR-NAAS, 2010). Also, it was reported that 34.5% of the cultivated lands are acidic in reaction (Maji *et al.,* 2012). As per the criteria of NBSS & LUP, total area of 93 Mha comes under different categories of soil acidity. Strongly acidic soils (6.35% of TGA), occur mainly in the Eastern Himalayan region and to a very small extent to the Western Ghats region of Kerala. The moderately acid soils (26 % of TGA) are common in the north eastern hill region including Sikkim and the Eastern plateau comprising of the Dandakaranya (Baster region of Chhattisgarh), Chotanagpur plateau (Jharkhand) and some hilly regions of Madhya Pradesh. About 21 Mha of the acidic soils are found in the north eastern region where the maximum area is covered in Arunachal Pradesh (6.8 Mha) followed by Assam (4.7 Mha), Meghalaya (2.24 Mha), Manipur (2.19 Mha), Mizoram (2.0 Mha), Nagaland (1.66 Mha).

Soil acidity, one of the major causes of soil degradation, which adversely affect the phytoavailability of the plant nutrients and crop growth in nearly 50% of the arable land of the world. Acidic soils are soils having pH less than 7.0 and soils having pH less than 5.5 are considered problematic due to severe deficiencies of phosphorus (P), calcium (Ca), magnesium (Mg) and molybdenum (Mo) and toxicity of aluminium (Al) and iron (Fe) (Panda and Chamuah, 2002). Acid soils are formed mainly due to the acidic parent material and leaching of bases caused by the heavy precipitation which is favoured by the soil forming factors like parent materials, temperature, vegetation and hydrological cycles on landscape. High rainfall leaches soluble nutrient such as Ca and Mg which are specifically exchanged by Al from the exchange sites and crop removal of bases are the major causes of formation of acid soils (Brady and

Weil, 2016). Continuous application of inorganic fertilizers without soil test can also contribute to increase in soil acidity in the long run. Nitrogenous fertilizers although it plays a significant role in increasing crop yields in contrary its excessive application and accumulation of phenolic acids can be the main driving factors for the decrease in soil pH value causing further soil acidification. (Guo *et al*., 2010; Hue, 1992).

The solubility and availability of important nutrients to plants is closely related to the pH of the soil (Marschner, 2011; Somani, 1996). Acid soil limits the availability of crucial nutrients such as P, K, Ca and Mg, and affects the microbial activities. Soil acidity and associated low nutrient availability is one of the constraints to crop production on acid soils (Bekele and Höfner, 1993; Mano and Haque, 1991). If pH of the soil is less than 5.5, phosphate can readily be rendered unavailable to plant roots as it is the most immobile major plant nutrient (Agegnchu and Sommer, 2000; Sanchez, 1977), and yields of crop grown in such soils are very low. In soil pH between 5.5 and 7, P fixation is low and availability to plants is higher. Toxicity and deficiency of Fe and Mn may be avoided if soil reaction is held within a pH range of 5.5 to 7; this pH seems to promote the readiest availability of plant nutrients (Sommani, 1996). The quantity of P in soil solution needed for optimum growth of crops lies in the range of 0.13 to 1.31 kg P ha^{-1} as growing crops absorb about 0.44 kg P ha^{-1} per day (Lawlor, 2004). The labile fraction in the topsoil layer is in the range of 65 to 218 kg P ha^{-1}, which replenishes soil solution P (Lawlor, 2004). Addition of P at very low pH (≤4.5-5.0) can result in precipitation as Al and Fe phosphates, whereas at high pH (>6.5) insoluble calcium phosphates can be formed (Haynes, 1984). High concentration of Al affects uptake and translocation of nutrients especially immobilization of P in the roots (Baquy *et al*., 2017; Fageria and Baligar, 2008), cell division, respiration, nitrogen immobilization and glucose phosphorylation of plants (Fox, 1979; Haynes and Mokolobate, 2001). Among the micronutrients, the deficiency of Zn has been reported in different soils of the world (Alloyway, 2008), including highly weathered and leached soils (Behera *et al*., 2011; Rautaray *et al.,*2003). Soil pH and organic matter content predominantly influence Zn availability in soil (Khaledian *et al*., 2017; Shuman, 1986). Enhanced soil pH alters soil Zn equilibrium and thereby influences Zn availability (Rengel, 2015).

At present, the productivity of rice is sub-optimal owing to the adverse effect of the acidic soil conditions which results in low fertility of the soil and thus average production and sub-standard quality of the crop in the region. Soil acidity problem in the region has adversely affected the soil and thus reduce the soil sustainability which needs to be corrected with proper management decisions. Management of soil acidity with proper amendments and addition of required nutrients are important to achieve higher yield of crops (Ratuaray *et al*., 2003). Recently more findings have emphasized the significant role of integrated soil fertility management involving combination of microbial inoculants, organic and inorganic fertilizers in elevating the productivity and improving soil health and sustainability of the environment in the long run (Devi *et al*., 2013). The use of lime, acid tolerant varieties, application of FYM/compost, and manures were found to be effective in reducing soil acidity and Al toxicity in different areas (Crawford *et al*., 2008). Addition of lime to acid soil decreases soil acidity and significantly enhances the status of basic cations, fixation of P and Mo is reduced by inactivating the reactive constituents and promote yield of the crops (Goulding, 2016). To enhance crop production in acidic soil conditions, application of lime alone cannot be the sustainable solution without considering the principle of balanced application of nutrients. Integrated Soil Fertility Management (ISFM) is one of the approaches to manage and improve soil health and fertility status (Agegnehu and Anede, 2017). It is a component of acid soils management which aims to improve crop productivity and soil health that uses a combination of organic and inorganic inputs. The positive effect of manure on crops has been explained on the basis of cation exchange between root surfaces and soil colloids (Sharma *et al*., 1990; Walker *et al*., 2004). The addition of organic fertilizers to acid soils has been effective in reducing phytotoxic levels of Al resulting in yield increases. The major mechanism responsible for this improvement are thought to be the formation of organo-Al complexes that renders the Al less toxic or direct neutralization of Al from the increase in pH caused by the organic matter. Studies have shown that residual effect of compost and manures applications significantly increased EC, soil pH levels, plant-available P and NO_3-N concentrations (Eghball *et al*., 2004).

Insufficient application of one nutrient causes the loss or the imbalance of the other nutrients, where Poss and Saragoni (1992) reported that an insufficient application of K fertilizer increases leaching losses of Ca, Mg and N. Reports from various sources have reported that phosphorous deficiency is quite common in the north-eastern regions of India accompanied with the toxicity of Fe and Al. The nutrient recommendation that is been used in the present scenario is proving to perform at a very low rate and the nutrient management practices have also performed very poorly in the past years due to improper management practices. Balanced fertilization with nitrogen, phosphorus and potassium fertilizers along with secondary and micronutrients in combination with organic manures helps in maintaining soil fertility. Therefore, taking into account the fertility problems in acidic soils and their inadequate management of the nutrients in the present scenario, the investigation entitled "Soil fertility management under direct seeded rice (*Oryza sativa* L.) in the acidic soil of Nagaland" was carried out with the following objectives:

1. To study the effect of soil fertility management on growth and yield of rice crop
2. To study the effect of soil fertility management on concentration and uptake of nutrients by rice crop
3. To study the effect of soil fertility management on soil properties
4. To find out the economics of the treatments under study

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Effect of soil fertility management on growth and yield in direct seeded rice

Takaki and Kushizaki (1970) conducted an experiment to study the tryptamine in zinc deficient crop as zinc ions are required for a variety of metabolic processes in plants. The enzyme required for the synthesis of tryptophan from indole and serine was found to require zinc for maximal activity. Zinc deficient plants contained significantly smaller amount of tryptophan than the control even before the appearance of visible symptoms of zinc deficiency. From the results obtained, they concluded that zinc is required directly for the synthesis of tryptophan and indirectly for the synthesis of Indole Acetic Acid.

Singh *et al*. (2000) carried out a field experiment to study the effect of planting time and nitrogen levels (60, 80 and 100 kg ha^{-1} N) and reported that each incremental level of nitrogen gave significantly higher grain yield over its preceding level.

Mirza *et al*. (2005) studies revealed that organic manures like green manuring significantly increased number of productive tillers, grain and straw yields. Continued supply of N from the organic source application resulted in a higher number of productive tillers until the reproductive stages of rice were reached. Phosphorus application also increased the number of productive tillers, grain and straw yields with the application of 90 kg ha^{-1}.

Barik *et al*. (2006) conducted a field experiment to assess the efficiency of integrated nutrient management constituting of vermicompost and FYM in combination with different doses of recommended fertilizer. Results showed that reduction of 50% RDF along with 10 t ha^{-1} Vermicompost significantly influenced the growth and yield attributes of *kharif* rice as compared with 100% RDF alone.

Khan *et al*. (2007) investigated the comparative use of nutrient management and residual effect of organic manures in combination with chemical fertilizers on crop productivity parameters. The highest yield for paddy and straw was recorded by the combined application of NPK+ GM + Zn (soil application) which was statistically different from all the treatments except with treatments NPK + FYM + Zn (soil application) and NPK + GM + Zn (root dipping). Integrated fertilization had pronounced residual effects on grain and straw yields of the crop. The results showed that organic manures especially NPK + FYM had direct and residual effects on both rice and wheat yields.

Ming *et al*. (2008) carried out an experiment to evaluate the effect of organic manure application with chemical fertilizers on rice yield and soil fertility under long-term double-rice cropping system. Four different treatments, i.e., no nitrogen with chemical P and K(PK), swine manure only (M), N, P and K fertilizers (NPK), and half chemical fertilizers combined half swine manure (NPKM) were included. They reported that NPKM treatment achieved the highest mean annual yield (68% higher than PK) with higher dry matter accumulation and nutrient absorption accompanied with higher panicle number per unit and filled grain number per panicle.

Rahman *et al*. (2008) carried out an experiment to evaluate the effect of sulphur and zinc levels on rice. They reported that among all the levels, T_4: $S_{20}Zn_3$ which was the highest level among all recorded the highest growth and yield parameters like plant height, number of effective tillers per hill, panicle length, grains $panicle^{-1}$, 1000 grain weight (g), grain and straw yield. Grain yield was higher in $S_{20}Zn_3$ compared to other treatments due to higher production of effective tillers per hill and increased grains $panicle^{-1}$.

Mandal *et al*. (2009) conducted an experiment to study the effect of Zn in combination with FYM and/or recommended dose of NPK on transplanted rice. Application of 10 kg Zn (5.0 + 2.5 + 2.5 kg ha^{-1}) in three split combinations with RD of NPK (60:13:25 kg ha^{-1}) recorded significantly higher growth, yield attributes, grain (4.5 t ha^{-1}) yield.

Bodruzzaman *et al*. (2010) conducted a field experiment to investigate on crop productivity with the application of inorganic fertilizers (NPKSZn) in combination with organic manures (poultry manure and FYM). They reported that plots with FYM+75% NPKSZn produced equivalent yields or higher yields as 100% NPKSZn.

Naing *et al*. (2010) investigated the effect of organic and inorganic fertilizers on growth and yield of five upland black glutinous rice varieties and soil property. The results from both years indicated that using combination of FYM and inorganic fertilizers increased shoot dry matter, LAI, tiller and panicle number per hill, grain number per panicle and grain yield when compared to the treatment of no fertilizer application and FYM alone. They further concluded that organic and inorganic fertilizers would be complementary in meeting the nutrients requirements of rice plants.

Siavoshi *et al*. (2011) carried out a field experiment with 5 levels of organic treatments (0.5, 1.0, 1.5, 2.0, 2.5ton ha^{-1}) mixed with inorganic fertilizers 50: 25: 25 kg ha^{-1} NPK and RDF 100: 50: 50 kg ha^{-1} NPK. The maximum grain and straw yield were found in plots treated with combination of inorganic fertilizer + 1.5 t ha^{-1} organic fertilizer. An increase in grain yield was maybe due to the increase 1000 grain weight, panicle number, number of fertile tillers, panicle length and decrease number of hollow spikelets per panicle.

Singh *et al*. (2011) carried out a three-year field experiment to ascertain the role of zinc and sulphur on rice performance and nutrient dynamics in plant and soil with the following treatments, 4 levels of zinc; 0 kg ha^{-1}, 4 kg ha^{-1}, 5 kg ha^{-1} and 6 kg ha^{-1} and 4 levels of sulphur; 0 kg ha^{-1}, 20 kg ha^{-1}, 30 kg ha^{-1} and 40 kg ha^{-1} respectively. They revealed that growth of rice was significantly affected by zinc and sulphur of which addition of 6 kg ha^{-1} zinc recorded the tallest plant height and combined application with 30 kg ha^{-1} S gave the maximum yield whereas the corresponding minimum yield was found in absolute control plots where no addition of zinc and sulphur was done.

Murthy (2012) reported that treatment which received recommended dose of fertilizers in combination with chromalaena compost @ 7.5 t ha^{-1} (100% RDF+CC2) recorded better plant height than control and treatment which received recommended dose of fertilizer alone at tillering, panicle initiation and at harvest stages. Their study suggested that the recommended dose of fertilizers along with organic manures was more advantageous than RDF alone.

Singh *et al*. (2012) conducted a field experiment on four levels of both sulphur and zinc and results revealed that rice plant height was significantly affect by sulphur and zinc. Tallest plant height, LAI and dry matter were recorded at maturity with application of 6 kg Zn. Maximum rice yield was recorded with the combined application of 30 kg sulphur and 6 kg zinc where corresponding minimum yield was recorded with absolute control plots where no application of zinc and sulphur was done during entire experimentation.

Uwanyirigira (2013) conducted an experiment with four nitrogen (urea) levels (0, 40, 80 and 120 kg ha^{-1}), three phosphorus (SSP) levels (0, 34 and 70 kg $P_2O_5ha^{-1}$) and reported that applied phosphorus had no significant effect on grain yield and did not affect any other yield component. Nitrogen application significantly improved the crop growth and yield by increasing plant height, leaf area, tillering and panicle numbers. They concluded with the recommendations of nitrogen and phosphorus rates at 109 kg N ha^{-1} and 34 kg ha^{-1} periodically depending on the actual soil P availability.

Das *et al*. (2014) studied the impact of integrated nutrient management practices on the physical properties and structural stability of soil aggregates, and the associated C contents after 18 years in rice-wheat rotation on a sandy loam soil and reported that integration of inorganic and organic sources incorporation improved soil aggregation and structural stability and resulted in higher C content in microaggregates which ultimately led to improved growth and yield of the crop. It also reported that integration brought about higher C stabilization in intensive rice-wheat system which is the prerequisite for the plant growth and development.

Ram *et al*. (2014) reported that application of sulphur @ 30 kg ha^{-1} through gypsum had the highest agronomic efficiency, crop recovery efficiency and physiological efficiency. Sulphur @ 30, 60 kg ha^{-1} through both gypsum and phosphogysum both increased the gain yield. However, significant response to sulphur was observed only up to 30 kg S ha^{-1} applied through wither sources.

Mondal *et al*. (2015) tried to evaluate the suitable proportion of organic manures and inorganic fertilizers along with biofertilizer to maximise growth and productivity of hybrid rice on sandy-loam lateritic soils. The crop having 50% RDF+50% RDN- mustard oil cake and 75% RDF+ 25% RDN through MOC+ biofertilizer significantly increased plant height, number of tillers m^{-2}, leaf area index, dry matter accumulation and crop growth rate at initial and vital period of grain growth over those of 25% RDF+75% RDN through MOC and 100% RDN through MOC.

Nath *et al*. (2015) reported that grain yield of rice obtained in the different nutrient management varied from 2.83 t ha^{-1} in unfertilized control to 4.07 t ha^{-1} in the integrated use of enriched compost (2 t ha^{-1}) and chemical fertilizers (25% NP). In long term, the yield advantage on application of organic sources of nutrients coupled with reduced chemical fertilizers was due to the addition of secondary and micronutrients along with the major nutrients and better synchrony of nutrient availability.

Singh *et al*. (2015) studied the efficacy of seaweed extract and fertility levels on growth, yield and economics of rice and reported that the morphological analysis of growth and yield of rice revealed that rice fertilized with 100% RDF manifested significantly higher plant height, total tillers m^{-2}, LAI, dry matter accumulation, crop growth rate, relative growth rate, grains $panicle^{-1}$, effective tillers resulting in significantly higher grain and straw yield as compared to 50% of RDF

Sudha *et al*. (2015) studied that zinc content in rice grains increased markedly by the application of zinc as compared to NPK alone.

Chand (2016) carried out a field experiment on influence of nutrient management practices on yield, nutrient uptake and soil properties under direct seeded rice and reported that treatment 100% RDF + 2t ha^{-1} VC + GA_3 spray was found to have significantly higher values of plant height, number of tillers m^{-2} and filled percentage over the control plot.

Kalala *et al*. (2016) carried out a pot experiment with the different levels of zinc (0, 5 and 10 mg kg^{-1}) and sulphur (0.20 and 40 mg kg^{-1}) to establish optimum rates and critical concentration of both the nutrients in soil as well as in rice shoot. They reported that with the addition of zinc and sulphur the grain yield recorded significant increase in eight and three out of ten soils tested. They concluded that the rates of 20 mg S and 5 mg Zn kg^{-1} soil was the optimum rates for soils with low S and Zn, respectively.

Bharose *et al*. (2017) conducted a field experiment to evaluate the effect of integrated nutrient management rice (*Oryza sativa* L.) productivity and soil fertility. They reported that highest yield was recorded with 100% NPK through inorganic fertilizers as it provided available nutrients to the plant for its development which was followed by 75% NPK RDF+ 25% N-FYM+GM+BGA. They concluded that use of different organic amendments in a cumulative manner with inorganic fertilizers met the nutrient requirement of rice which resulted in better yield of the crop.

Imade *et al*. (2017) studied the effect of organic manures in combination with inorganic fertilizers on transplanted rice under rice-green gram cropping sequence and pooled data revealed that the application of general RDF 100-30-00 kg NPK ha^{-1} + FYM @ 10 t ha^{-1} recorded significantly higher growth attributed viz., plant height, total number of tillers, LAI, dry matter accumulation per hill over control. It also gave significantly higher results in yield attributes viz., number of panicle m^{-2}, number of grains per panicle, panicle length, test weight, seed and straw yield.

Kumar *et al*. (2017) revealed from the experiment that 75% RDF alongside with green manuring of dhaincha in situ incorporated in alternate year recorded significantly higher growth and yield attributes over rest of the treatments except 100% as inorganic fertilizers. Increase in yields were recorded with 100% RDF but was comparable when 50 or 75% RDF was incorporated together with organic sources.

Noor (2017) compiled a review on nitrogen management and regulation for optimum nitrogen use efficiency which critically focuses on fertilizer management and regulation in farming system with high population density. It was reported that rational use of fertilizers with right dose at right time, as well as integrated agronomic management practices are proposed. N utilization efficiency, referred to as grain yield at the expense of taken up N, was predominantly associated with photosynthetic machinery of the plants and better assimilation of photosynthates in grains, having sufficient storage proteins for maximum translocation.

Shalini *et al*. (2017) conducted a field experiment to study the effect of iron (FS 1% and SA 30 kg ha^{-1}), zinc (FS 0.5% and SA 25 kg ha^{-1}) and organic manures application (FYM 2.5, 5.0 t ha^{-1} and vermicompost 1.5, 3.0 t ha^{-1} and brown manure) on direct seeded dry rice. Thus, they reported that vermicompost applied in conjunction with brown manure (RDF+BM+ 1.5t VC) resulted in production of more dry matter, a greater number of effective tillers and higher grain yield and higher gross return, this treatment was found at par with combined foliar application of iron and zinc (RDF+1 FS of 0.5 % $ZnSO_4$+ 3 FS of 1% $FeSO_4$) yielded more than their combined soil application than their sole application.

Singh *et al*. (2017) conducted a field experiment with four levels of zinc viz., 0, 5, 10 and 15 kg ha^{-1} and four levels of sulphur viz., 0, 15, 30 and 45 kg ha^{-1}. Results revealed that all the growth, yield attributes and yields were increased specifically under 15 kg Zn ha^{-1} applied. Number of shoots $hill^{-1}$, plant height and dry matter accumulation, yield attributes and grain and straw yields of rice were significantly higher with sulphur applied at 45 kg ha^{-1}.

Apon *et al*. (2018) reported that integrated nutrient management with 100% RDF+ FYM @ 5t ha^{-1} enhanced the growth and yield of both the local rice cultivars. The application of 100% RDF+ FYM @ 5t ha^{-1} recorded the highest number of panicle m^{-2} (120), length of panicle (28.93 cm), test weight (30.55 g), grain yield (3140.28 kg ha^{-1}) and straw yield (8888.89 kg ha^{-1}). It also gave the highest harvest index (32.68%) and concluded that it was more suitable under rainfed upland conditions of Nagaland.

Kumar *et al*. (2018) conducted an experiment to evaluate the influence of integrated use of NPK, Zn, FYM and Biofertilizers on soil properties of rice. Application of 50% NPK, Zn + Biofertilizer (PSB+BGA) + FYM (10 t ha^{-1}) significantly increased the growth and yield as well as soil fertility as compared to chemical fertilizers alone. It was observed that significant increase in grain and straw yield was observed with 100% NPK and biofertilizers in comparison to other treatments. In terms of grain and straw yield integrated nutrient management proved more superior than alone application of chemical fertilizers or biofertilizers and manures.

Singh *et al*. (2018) conducted an investigation on the effect of integrated nutrient management on growth and yield of rice to evaluate the impact of continuous use of inorganic fertilizers with organic nutrition on productivity, economics and soil fertility status. They reported that growth attributes like plant height, number of tillers m^{-2}, LAI, and dry matter accumulation were found highest with the treatment T_5 (50% RDF+50% N-FYM) but remained at par with treatments which had substitution of either 25 or 50 % N through organic sources. The difference in growth attributes were statistically alike between 100% RDF and treatments supplicated with either 25 or 50% N through organic sources. Grain yield, straw yield and harvest index of rice increased up to 100% RDF and more increased when 20 or 50 % nutrients substituted through organic sources.

Rajpal Singh *et al.* (2018) revealed that application of 50 and 100% NPK and organic manures significantly increased plant height, number of tillers $plant^{-1}$ and yield of rice over control. The maximum grain and straw yield were obtained with 100% NPK + 10t FYM ha^{-1} than 50 % NPK + 10t FYM ha^{-1} and 100% NPK alone treatment.

Singh *et al*. (2018) reported that application of 20 kg ha^{-1} sulphur and 15 kg ha^{-1} zinc recorded the highest number of effective tillers m^{-1}, filled grains $panicle^{-1}$, grain and straw yield and harvest index over the other treatment.

Ganguly *et al*. (2019) observed that the growth and yield attributes of rice crop viz., number of panicle m^{-2}, number of filled grain $panicle^{-1}$ and nutrient uptake were favourably influenced by combined application of inorganic fertilizers and organic manures.

Mondal *et al*. (2020) conducted a study on the effect of different nutrient management practices on transplanted rice and results revealed that rice plots fertilized with the higher dose of NPK @ 80, 40, 40 recorded highest plant height, LAI, dry matter accumulation but the combination treatment of NPK @ 60:30:30 (kg ha^{-1}) + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest tiller and seed yield than the other treatments.

Rama *et al*. (2020) reported that integrated nutrient management (INM) expressed significantly better results on growth, yield, nutrient content and economics of summer rice. The treatments with 75% RDN along with 25% vermicompost and 75% RDN along with 25% FYM recorded enhanced growth, nutrient and productivity which were at par with 100% RDN and the lowest results were found with control (no fertilizers).

Singh *et al*. (2020) reported that significantly higher value of all the yield attributes were recorded with the application of 100% NPK (150:75:60 kg ha^{-1}) through inorganic fertilizers as compared to rest of the treatments was found at par with 75% NPK + 25% N through bio compost. They concluded that adequate nutrient supplying system favoured vegetative growth and development which resulted from increased fertilization which contributed higher yield attributes.

Neti *et al*. (2022) reported that various observations on growth characteristics including plant height, number of tillers $hill^{-1}$, and dry matter production, crop growth rate was significantly increased with application of 50% RDF+ 50% N through green leaf manure which was followed by 100% NPK (120:60:40). Grain and straw yield were also reported with the integrated use of inorganic and organic sources (50% RDF+ 50% N) closely followed by 100% RDF.

Saha *et al*. (2020) reported that use of 100% NPK+FYM @10 t ha^{-1}+$ZnSO_4$ @ 20 kg ha^{-1}+ borax @ 10 kg ha^{-1} showed the highest growth attributes such as number of tillers $plant^{-1}$, dry matter accumulation. It also recorded the highest number of panicles m^{-2}, grain, straw and biological which was significantly higher than all the other treatments. Therefore, they concluded that application of zinc and borax at their higher rates i.e., 20 kg and 10 kg ha^{-1} respectively along with 100% NPK+FYM @10 t ha^{-1} exhibited the best results.

Shankar *et al*. (2020) reported that grain, straw and biological yield were significantly influenced with the different integrated nutrient management. The highest grain and straw yield recorded in treatment 75% RDN + 25% RDN through poultry manure, was statistically at par with treatments 50% RDN + 50% poultry manure, 100% RDN, 50 % RDN + 50% FYM and 75% RDN + 25% FYM. The lowest was recorded with plot with no fertilizer treatment which produced the least yield as compared to other treatments.

Behera *et al*. (2021) undertook a study on INM effect on rice variety and reported that application of 75% RDN + 25% N -FYM + $ZnSO_4$@25 kg ha^{-1} resulted the best superior growth performances, yield attributes and maximum grain yield.

Narayan *et al*. (2021) studied sulphur nutrition and its role in plant growth and development. they reported that sulphur is a very important component of plant metabolism and its analysis with different dimensions is highly required to improve the overall well-being of plants.

Yadav *et al*. (2021) conducted a field experiment to evaluate the effect of INM on yield and economics of aromatic rice and reported that application of 100% NPK + 25% Vermicompost registered taller plant height, number of tillers m^{-2}, number of panicle m^{-2}, grain per panicle and length of panicle. Grain and straw yield followed by treatment 100% NPK + 25% N through FYM was reported in this study.

Zenda *et al*. (2021) reported that sulphur plays crucial roles in plant growth and development, with its functions ranging from being a structural constituent of macro-biomolecules to modulating several physiological processes and tolerance to abiotic stresses.

Bajpai *et al*. (2022) reported from the investigation that the application of T_4: 150% RDF produced the highest growth and yield attributing parameters which was statistically similar to the treatments of T_3: 100% RDF, T_5: 100% RDF+$ZnSO_4$, T_6: 100% N and P_2O_5 and T_8: 100% RDF+FYM at all stages of growth. The lowest growth and yield attributing parameters were observed under control where no nutrient was applied during both the years and on mean basis.

Parida *et al*. (2022) did a study on genetic control and molecular regulation effecting the panicle morphology on grain filling and rice yield. The investigations have revealed several reasons for poor filling of the grains in the inferior spikelets of the compact panicle, which are otherwise genetically competent to developed into well filled grains.

Cakmak *et al*. (2023) studied the functions of micronutrients and reported that zinc plays a key role in the structural and functional integrity of cell membranes, biosynthesis of proteins, detoxification od radicals and synthesis of lignin.

Hawkesford *et al*. (2023) explained the role of macronutrients nitrogen, sulphur, phosphorus, magnesium, calcium and potassium in plant metabolism and growth together with the consequences of deficiency and toxicity. Nitrogen is an element required in largest quantity by plants and is a major driver for crop yield. It also plays a central role in plant metabolism as a constituent of proteins, nucleic acids, chlorophyll and secondary metabolites. S is taken up as sulphate and assimilated in S-containing amino acids such as cysteine which are used to synthesize S-containing enzymes. N and S are both important constituents of seed storage proteins.

Khampuang *et al*. (2023) investigated the response of rice (*Oryza sativa* cv. Osmancik 97) production and grain Zn accumulation to combined zinc and sulphur fertilization where they reported that the lowest rate of S (2.5 mg kg^{-1}) at adequate soil Zn (5 mg kg^{-1}) treatment increased grain yield by 68% compared with the same S rate (2.5 mg kg^{-1}) at low Zn (0.25 mg kg^{-1}) supply. Plants with the adequate S rate (50 mg kg^{-1}) at low Zn (0.25 mg kg^{-1}) and adequate Zn (5 mg kg^{-1}) supply produced the highest grain yield with increase of 247% and 143% compared with low S rate at low Zn and adequate Zn respectively. The results indicated that the synergistic application of soil Zn and S improves grain production and grain Zn yield, therefore highlighted the importance of increased grain yield by increasing S fertilization.

Tsukru *et al*. (2023) reported that application of 100 kg N ha^{-1} along with 40 kg P ha^{-1} proved to have improved the crop growth rate and relative growth rate as compared to control and other levels of N and P. Combination treatment of the two-nutrient proved to have performed significantly better than N or P alone as deficiency of any of the nutrients led to poor growth and development of the plant which ultimately leads to less grain formation.

2.2 Effect of soil fertility management on nutrient content and uptake in direct seeded rice

Saleque *et al*. (1998) conducted an experiment to evaluate the response of rice to potassium fertilizer and reported that application potassium significantly increased rice yield as it increased the potassium content in the grain and not in straw as this might be due to uptake by the above portion of the plant is mostly translocated to root instead of grain for their profuse growth to facilitate higher N uptake.

Sriramachandrasekharan (2001) reported the highest iron uptake with plots which received organic sources.

Das *et al*. (2002) who reported the interaction between Mn and available N was found to be positive therefore the Mn uptake by the crop was higher in the plots which had higher addition of nitrogen.

Shamina and Hug (2002) reported that yield and uptake of N, P, K, and S at consecutive stages of growth of sunflower were affected if sulphur was excluded. Sulphur had synergistic effect on the yield and nutrient uptake. Application of sulphur between 60-80 kg ha^{-1} increased significantly the seed uptake of N, P, K, and S. however, higher dose of sulphur tends to decrease the nutrient uptake in all years. Plants grown without sulphur had the lowest uptake.

Mandal *et al*. (2003) reported that organic sources green manure and nitrogen application improved the soil physical and chemical properties which promoted root growth and increased yields both in rice and wheat. In organic manure treated plot, root mass per unit volume of soil increased which resulted in a larger total root surface available for the uptake of nutrients.

Ali *et al*. (2004) caried out a field experiment with five levels of sulphur S_0, S_{10}, S_{20}, S_{30}, S_{40} and two levels of phosphorus P_0 and P_{35} to study the interaction effects of S and P on growth and yield of BRRI dhan29 rice variety. It was observed that combination of S and P (S_{40} P_{35}) increased the nutrient concentrations and uptake by rice plants and found it suitable for the growth and yield of the rice variety.

Chander *et al*. (2007) reported that incorporation of FYM resulted in significant and consistent increase in calcium uptake in cauliflower. A significant response to FYM can be interpreted in terms of its effects on improvement in soil exchangeable Ca.

Khan *et al*. (2007) studied the response of zinc levels along with basal dose of NPK in wheat -rice system and reported that zinc application significantly affected zinc concentrations in leaves by the cumulative application of 10 kg Zn ha^{-1} and full dose of NPK.

Mithun *et al*. (2007) reported that integrated use of fertilizers with organic source resulted in higher total micronutrients uptake of rice crop as compared to application of fertilizers alone.

Agarwal (2008) reported that balanced fertilization significantly affects the nutrient content and uptake by a crop which further affects the yield of the crop. The crop yields of rice crop in the 36th year of experimentation revealed that highest production of 5.4 t ha^{-1} of rice grain was obtained by combined application of FYM and 100% NPK. He highlighted the beneficial effects of FYM which have favourable effects on the availability of macro and micronutrients and better uptake of nutrients by rice grain and straw as compared to 100% NPK alone.

Kumar *et al*. (2008) found that application of FYM along with 100% NPK produced significantly higher grain yield of rice than 100% NPK alone which may be due to better content of nitrogen, phosphorus and potassium in grain.

Rahman *et al*. (2008) reported that application of 20 kg ha^{-1} sulphur along with 3 kg ha^{-1} zinc significantly enhanced the sulphur and zinc uptake of the crop as compared to other levels and no application of the nutrients.

Srinivasan and Angayarkanni (2008) conducted a study of treatment combination with five levels of N (0, 50, 100, 150 and 200 kg ha^{-1}), four levels of P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) and three levels of K_2O (0, 40 and 80 kg ha^{-1}) with FYM (0, 12.5 kg ha^{-1}) and Azospirillum (0, 2 kg ha^{-1}) and reported that nutrients uptake increased from Strip I to IV with chemical fertilizers along with FYM + Azospirillum.

Alina (2011) reported that low molecular weight compounds liberated during decay of plant and animal residues as well as those applied with sewage sludge may greatly increase the availability of Cu to plants.

Kabir *et al*. (2011) reported that balanced fertilization to rice gave significantly higher N, P, K, S and Zn uptake both in grain and straw as compared to control. He recorded that application of T_6 – N_{140} P_{40} K_{80} S_{30} Zn_4 gave highest uptake but was statistically similar to T_5 – N_{120} P_{35} K_{70} S_{25} Zn_3 and T_2 – N_{60} P_{20} K_{40} S_{10} Zn_1 in pretext to uptake by the crop.

Singh *et al*. (2012) carried out a three-year field experiment to ascertain the role of zinc and sulphur on rice performance and nutrient dynamics in plant and soil with the following treatments, 4 levels of zinc; 0 kg ha^{-1}, 4 kg ha^{-1}, 5 kg ha^{-1} and 6 kg ha^{-1} and 4 levels of sulphur; 0 kg ha^{-1}, 20 kg ha^{-1}, 30 kg ha^{-1} and 40 kg ha^{-1} respectively. Sulphur and zinc had significant influence on nutrient content and uptake as they play an important role in growth and development. Highest nitrogen uptake was also reported with the addition of 6kg ha^{-1} zinc but highest P and K uptake was recorded with plots supplemented with no zinc addition and sulphur at 40 kg ha^{-1}.

Subehia and Spehya. (2012) reported that nitrogen substitution through different organics increased significantly the productivity and NPK uptake by rice and wheat. The total uptake of N, P and K by rice-wheat system was highest with the combination of 50% NPK along with 50% N through FYM over control.

Paul *et al*. (2013) reported grain yield obtained with application of $N_{180}P_{40}K_{40}$ + Znf + FYM in rice-wheat at Pantnagar which were statistically higher than other treatments except for $N_{120}P_{40}K_{40}$ + FYM, $N_{180}P_{60}K_{40}$ + Znf + FYM and $N_{180}P_{60}K_{40}$ + Znf. He highlighted the importance of balanced supply of N, P, K and Zn along with FYM that led to better nutrient content in rice.

Islam *et al*. (2013) conducted an experiment to study the effect of fertilizer and manure on growth, yield and grain nutrient concentration of Boro rice under different water management practices and reported that among the fertilizer treatments, treatment which received integration of inorganic fertilizer with organic manure gave the highest concentration of grain and straw N, P, K, and S respectively.

Niraj *et al*. (2013) concluded that application of sulphur and zinc to rice crop increased the sulphur and zinc uptake of the crop as compared to control.

Rani and Sukumari (2013) reported that the total nutrient uptake (N, P, K, Fe, Mn and Zn) increased due to nutrients sources applied through integrated nutrient source other than either organic or inorganic sources alone.

Shormy *et al*. (2013) reported the nutrient contents (N, P, K, S, Ca and Mg) and their uptake by grain and straw were significantly influenced by application of different treatments except the S content in grain. The highest values of most of the parameters were obtained from recommended dose of NPKS + PSB treatment which was statistically identical with GM @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} + PSB, GM @ 10 t ha^{-1}, GM @ 5 t ha^{-1} + FYM @ 5 t ha^{-1} treatment combinations in many cases.

Ram *et al*. (2014) studied the effect of sulphur levels on growth, productivity and economics of aerobic rice and reported that irrespective of their sources, application of sulphur had a positive and significant influence on sulphur uptake of the crop with sulphur @ 30 kg ha^{-1}.

Dash *et al*. (2015) observed that combined application of NPK with S, B and Zn recorded highest yield, nutrient accumulation as well as uptake and maintained soil fertility. Omission of N, P or K from the fertilizer scheduled and in absence of B, Zn and S or B, Zn, S addition, NPK accumulation decreased in both grain and straw. The reduction was in the order of Zn, B, S, Zn B S indicating that deletion of Zn B S from the schedule significantly decreased the nutrient accumulation.

Lakshmi *et al*. (2015) studied the effect of integrated nutrient management on kharif rice and its residual effect on green gram and reported that their uptake was higher with INM practices especially when the organic manure was incorporated together with the recommended dose of fertilizers.

Mahmood and Ali (2015) reported that maximum tillers, panicle length, grain panicle^{-1} and paddy yield with fertilizer phosphorus application @ 80 kg P_2O_5 ha^{-1} along with crop residue incorporation, which was considerably better (13%) than that of sole P application @ 120 kg P_2O_5 ha^{-1}. Higher concentration of P, K and Ca^{2+} in plant tissues (rice and wheat) were found where P was applied @ 80 kg P_2O_5 ha^{-1} along with crop residue incorporation or 120 kg P_2O_5 ha^{-1} alone, while Na^{+} and Mg^{2+} concentration decreased with increasing the rate of P.

Shahid *et al*. (2015) reported that application of FYM in combination with chemical fertilizers increased the K availability in soil. It was also reported that application of FYM alone or in combination with chemical fertilizers increased the DTPA-extractable Fe, Mn and Zn over the control treatment. The treatment with NPK+FYM had the soil highest soil DTPA extractable - Fe, Mn and Zn.

Chand (2016) carried out a field experiment on influence of nutrient management practices on yield, nutrient uptake and soil properties under direct seeded rice and reported that treatment 100% RDF + 2t ha^{-1} VC + GA_3 spray, the N and P content in grain were found significant at harvest but non-significant in straw. The N, Fe and Zn uptake in grain, straw and total uptake were significantly higher in treatment 100% RDF + 2t ha^{-1} VC + GA_3 spray than compared to other treatments.

Islam *et al*. (2016) reported with the increasing levels of sulphur up to 200% improved the sulphur content both in grain and straw as compared to lower levels of sulphur control due to higher nutrient use efficiency by the crop. He advocated the need to prioritize the improvement of nutrient use efficiency with nutrient uptake should be conducted to boost yield of the crop.

Sireesha *et al*. (2017) observed that higher nutrient uptake by rice growing in Jagtial district was mainly due to the higher dry matter accumulation since FYM supply both the important major and minor nutrients along with organic acids that provides a good soil physical condition for plant growth.

Kumar *et al*. (2017) conducted a field experiment to study the response of different levels of sulphur and zinc on rice crop and reported the beneficial effect of sulphur and zinc where, its nutrient content when observed attributed to higher uptake of all the nutrients on account of correction of deficiencies like sulphur and zinc nutrient resulting in elimination of factor, which was limiting the growth and nutrient contents in the control. He found that application of sulphur up to 60 kg ha^{-1} and zinc 5 kg ha^{-1} along with recommended dose of NPK gave the highest content in grain and straw and is optimum for obtaining maximum yield of quality rice with rich in sulphur and sulphur content.

Puli *et al*. (2017) conducted a field experiment to find out the effect of different sources of nutrients on secondary (Ca and Mg) and micronutrient (Fe, Mn, Cu and Zn) uptake by rice at various growth periods. They reported that the nutrient content in rice at various growth periods was significantly increased with the application of 100% NPK in combination with FYM @ 10 t ha^{-1}.

Rani and Latha (2017) studied the influence of secondary and micronutrients viz. calcium, magnesium and boron on nutrient uptake of rice and reported that uptake of nutrients like Ca, Mg and B crop were positively correlated with yield except of Fe and Mn due to balanced fertilization.

Srivastava and Singh (2017) reported that uptake of NPKS and Zn was significantly improved under treatments having organic manure along with inorganic levels (100%, 75% and 50% NPK) of fertilizer over alone levels of inorganic fertilizer.

Bora *et al*. (2018) reported that treatment with recommended dose of fertilizer to rice, $N_{120}P_{40}K_{40}$ + Zn gave higher values of nitrogen, phosphorus and potassium content and uptake, over other treatments with only inorganic fertilizers application. But FYM application along with NPK and NPK + Zn enhanced the concentration of nutrients as well as their uptake and that increased significantly with the application of N, P, K, Zn and FYM applied in balanced combination.

Dixit *et al*. (2018) conducted a field experiment to study the effect of sulphur and zinc on yield, quality and nutrient uptake by hybrid rice and reported that application of 40 kg ha^{-1} S recorded significantly high grain and straw sulphur uptake. A positive response of hybrid rice to zinc application was also notices significantly up to zinc dose of 10 kg ha^{-1}. Increasing the dose of sulphur and zinc enhanced significantly their uptake by hybrid rice crop. Nitrogen, Phosphorus and Potassium uptake in crop was also increased significantly with sulphur and zinc application.

Kumar *et al*. (2018) reported that combined application of NPKZn with organic sources like FYM and biofertilizers improved the nutrients uptake increased significantly over control. It is concluded that under rice crop combined application is more superior in increasing crop productivity as compared to sole application of chemical fertilizers.

Singh *et al*. (2018) reported that the highest total uptake of N, P, K, Zn, Fe and Mn were recorded with 100% NPK + 10t FYM ha^{-1} + GM while the lowest values of total uptake both in grain and straw of these nutrients were recorded under control.

Alexandre *et al*. (2019) conducted a greenhouse experiment in upland rice and cowpea and observed an increase in the amount of K and P nutrient content and reduction in levels of Ca and Mg after application of biochar.

Latha *et al*. (2019) conducted a field experiment to study the effect of INM on major nutrient content and uptake by rice and reported that nitrogen content in rice ranged from 1.71% to 2.22% and 1.58% to 2.18%, phosphorus content was ranged from 0.34% to 0.51% and 0.14% to 0.58% and potassium content was ranged from 1.65% to 2.20% from active tillering to grain filling stage. Nitrogen uptake was ranged from 49.48 kg ha^{-1}, 49.70 to 135.2 kg ha^{-1}, phosphorus uptake ranged from 10.48 to 36.31 kg ha^{-1} and potassium uptake ranged from 55.03 to 146.94 kg ha^{-1} from active tillering to grain filling stage.

Biswas *et al*. (2020) evaluated the quality parameter, nutrient content and nutrient uptake in rice and recorded the highest nitrogen and potassium content by rice grain and straw with the application of 75% RDF + 25% N through vermicompost.

Mousomi *et al*. (2020) carried out an experiment to study the effect of fertilizers on nutrient content and uptake of Aromatic Local Transplant Aman rice varieties in Acid soil and reported that there was significant interaction among different fertilizer packages and varieties on nutrient content and uptake of different varieties. He further reported that F_1 treatment which had RDF for Aman rice 45-10-20-10-0.5 kg ha^{-1} N-P-K-S-Zn recorded the highest NPKSZn content and uptake both in grain and straw as compared to other treatment levels 2/3rd of RDF, 1/3rd RDF and control respectively. He found that application of recommended dose of fertilizer increased yield that resulted in increased uptake and also proved that higher levels performed much better as compared to lower levels.

Sahu *et al*. (2020) showed that the highest nitrogen, phosphorus and potassium content and uptake by the grain and straw was recorded in the treatment receiving 100% NPK + 5 t FYM + $ZnSO_4$ @ 25 kg ha^{-1} + lime @ 3 q ha^{-1} (T_8) which was significant over all other treatments followed by the treatment 100% NPK + 5 t FYM + $ZnSO_4$ @ 25 kg ha^{-1}. The lowest nutrient content and uptake by grain and straw was obtained in control.

Sahu and Chaubey (2020) advocated the inclusion of organic manures along with chemical fertilizers for enhancing the nutrient content and uptake in the crop as FYM results in the better availability of N, P and K in the soil to the rice crop. The application of organics and chemical fertilizers increased crop yields that resulted in increased uptake. He reported that increased in nutrient uptake was directly related to crop yields.

Tiwari *et al*. (2020) results revealed that nutrient content and uptake were significantly influenced due to different treatments. The nutrient content and its uptake by rice was observed higher with the application of 100% RDF through (IF) + 25% RDN through Neem Cake as compared to other treatments. The lowest nutrient content and uptake was recorded with 100% RDF through FYM.

Cui *et al*. (2022) studied the effect of Cu-N interaction on the growth and yield parameters of the rice crop and the results showed that the effect of N was more pronounced than that of Cu supply. The Cu supplied significantly improved the uptake of N while the N supply significantly promoted root to root translocation and distributed more Cu into the shoot and leaves. They concluded that Cu and N had synergistic effect.

Garnaik *et al*. (2022) reported that sulphur uptake was about 8 kg ha^{-1} higher in NPK + FYM + Lime plots as compared to control and 59% in comparison to NPK applied plots.

Kumar *et al*. (2022) reported that the plant N, P and K uptake was enhanced by the application of 100% NPK along with bioagents and organic sources of nutrients. He added that balanced and regular supply of the nutrients to the crop attributed to stimulate plant physiological processes leads to increase leaf area, produce more photosynthates and nutrients acquired resulted in increase in dry matter assimilation.

2.3 Effect of soil fertility management on soil properties in direct seeded rice

Hue *et al*. (1986) carried out a study to observed the aluminium detoxifying capacity of organic acids and reported that the most effective acids in alleviating toxic effects were citric acid, oxalic and tartaric. They also reported that there was a wide variation in both concentration and kinds of organic acids in soil solution of different eluviated horizons. Those in forest generally contain more acids than their cultivated counterparts and because of the microbial activity.

Misra *et al*. (1987) reported that higher contribution made by pH dependent acidity in the total acidity pool may be due to high content of Fe and Al oxides and organic matter in the soils.

Das *et al*. (1991) reported that the higher potential acidity may be due to the higher percentage of organic matter in the soil which contributed to total acidity through their functional groups like carboxylic and phenolic hydroxyl groups.

Kumar *et al*. (1995) reported a negative correlation between soil pH with total potential acidity and pH dependent acidity.

Swarup and Yaduvanshi (2000) reported that application of 100% NPK plus GM or FYM was significantly better than 150% NPK. The soil organic carbon, available Zn and Mn significantly increased by application of NPK with FYM over rest of the treatments. Similar trends also observed in case of available P and K status of soil.

Haynes and Mokolobate (2001) gave a report that during residue decomposition, there is a transitory increase in soil pH which induces a decrease in exchangeable and soil solution Al through their precipitation as insoluble hydroxy-Al compounds. It also confers a greater negative charge on the oxide surfaces and thus tends to decrease P adsorption. The increase in pH had been attributed to a number of causes including oxidation of organic acid anions present in decomposing residues, ammonification of residue N, specific adsorption of organic molecules produces during decomposition and reduction reactions induced by anaerobiosis. Complexation of Al by the newly formed organic matter will tend to reduce the concentrations of exchangeable and soluble Al present. As organic residues decompose, P is released and this can become adsorbed to oxide surfaces which in turn, reduce the extent of adsorption of subsequently added P thus increasing P availability.

Venkatesh *et al*. (2002) carried out a field experiment to study the effect of P levels, FYM and Lime on yield, P use efficiency by maize and forms of acidity. They reported that application of Lime and FYM along with P reduced the different forms of acidity and the exchangeable acidity registered a decline up to 72% on liming.

Katyal *et al*. (2003) reported that organic carbon status and available P increased due to integrated use of organic manures and inorganic fertilizers over initial. There was also improvement in available soil N and K over their initial.

Sharma *et al*. (2003) conducted a study on status of micronutrients and effect of soil properties on their status and reported that available Zn, Cu, Fe, Mn and B showed positive correlations with silt plus clay and organic carbon, and negative correlations wit pH and calcium carbonate content.

Narambuye and Haynes (2006) conducted a lab experiment to investigate the effect of the addition of two rates of a range of organic amendments to an acid soil on pH and exchangeable Al and soluble Al. They reported that soil pH was increase, exchangeable plus total and monomeric Al in solution were decreased by the addition of all the organic amendments; the effect was greater at higher rate of addition. The major mechanism responsible for the elevation of pH were suggested to be the proton consumption capacity of humic material present in compost and manures, decarboxylation of organic acid anions during decomposition of plant residues and manures.

Ano and Ubochi (2007) studied the mechanism of reaction leading to neutralisation of soil acidity by animal manures with five animal manures: rabbit manure (RBM), swine manure (SWM), goat manure (GTM), poultry manure (POM) and cow manure (COM) with rates equivalent to 10, 20, 30 and 40 t ha^{-1} respectively. They reported that mechanism that best explained the neutralization reaction was found to be microbial decarboxylation of calcium-organic matter complex leading to the release and subsequent hydrolysis of calcium ions. The hydroxyl ions released in the hydrolytic reaction then reacts with both the exchangeable hydrogen and aluminium ions to form water soluble and insoluble aluminium hydroxide [$Al(OH)_3$] respectively.

Kundu *et al*. (2007) analysed results of long-term experiment under sandy loam rainfed conditions to determine the influenced of different combinations of NPK fertilizer and fertilizer + FYM at 10 Mg ha^{-1} on SOC content. It was reported that concentration of SOC increased to 40 and 70% in the NPK + FYM treated plots as compared to NPK (43.1 Mg C ha^{-1}) and unfertilized control plots (35.5 Mg C ha^{-1}) respectively.

Mehra and Jat (2007) carried out a study to delineate the area of sufficiency and deficiency of micronutrients and their relationship with soil properties and they reported that soil micronutrients increase with increase in soil organic carbon, high CEC and finer fractions of soil like silt and clay while it decreases when there was increase in soil pH and high $CaCO_3$ content which form insoluble complexes with the metal ions.

Brady and Weil (2008) explained the colloidal complexes of soils is the fine and supreme functional section of the organic and inorganic soil particles where most of the chemical phenomenon takes place. The inorganic or clay colloidal complexes of soils occurs as fine particles, organic colloidal fraction which is the site of important processes in soil governing ion exchange, nutrient availability and fixation, and soil physical properties. The organic colloidal complexes in soils are mainly because of the existence of humus.

Fageria and Baligar (2008) explained the mechanism of soil acidity due to reaction of aluminium ions with water which gives species of aluminium and hydrogen ion responsible for soil acidity. Increased soil acidity causes solubilization of Al, which can be the primary source of toxicity to plants.

Gang *et al*. (2008) carried out an experiment to evaluate the effect of organic manure application with chemical fertilizers on rice yield and soil fertility under long-term double-rice cropping system. Four different treatments, i.e., no nitrogen with chemical P and K(PK), swine manure only (M), N, P and K fertilizers (NPK), and half chemical fertilizers combined half swine manure (NPKM) were included. They reported that NPKM treatment reported an increase in average nitrogen use efficiency (36.3%) and soil organic matter (18.5%) and concluded that organic manure application integrated with chemical fertilizers increased the yield and nitrogen use efficiency of rice with reduction of risk in environmental pollution and improved soil fertility greatly.

Yadav (2008) found out the available Fe, Mn, Cu and Zn showed positive and significant correlation with organic carbon and also found negatively and significantly with pH and calcium carbonate content of soils.

Bodruzzaman *et al*. (2010) conducted a field experiment to investigate soil fertility with the application of inorganic fertilizers (NPKSZn) in combination with organic manures (poultry manure and FYM). They reported that soil pH increased with the addition of poultry manure but unchanged for FYM and inorganic fertilizers, while percent organic matter and percent N, available P, Exchangeable K increased or remained unchanged for the organic manure plots while reduction in the inorganic fertilized plots. From the soil analysis results they concluded that continuous application of organic manures could enhance the % organic matter content in the soil in time.

Kumar *et al*. (2010) observed that application of higher dose of fertilizers enhanced nitrogen, phosphorus and potassium uptake in crops due to abundant availability in the soil pool which led to its higher uptake by the crop.

Kumar and Babel (2010) carried out a study to evaluate available micronutrient (Fe, Cu, Zn Mn and B) status and their relationship with soil properties. The availability of micronutrients indicating positive significantly correlated with silt, clay, organic carbon and CEC of soils, whereas negative and significantly correlated with sand, calcium carbonate and pH of soils.

Kumar and Singh (2010) conducted an experiment on the effect of green manure and FYM on yield and fertility status of rice- wheat cropping system and reported the build-up of organic carbon in the soil with combined application of organics and inorganics to preceding crop. It also reported that available nitrogen in soil was enhanced with the application of organic manure FYM along with 100% NPK.

Sidhu and Sharma (2010) reported that the available micronutrients in soil increased with the increased in organic carbon content and decreased with increase in sand content, pH and calcium carbonate.

Urkurkar *et al*. (2010) observed that integrated nutrient management coupled with organic manures like FYM and fertilizers enhanced the soil fertility in Inceptisols. He reported that soil pH declines in all the treatments containing FYM/ green manures except for treatment which received only inorganic fertilizers. Organic carbon, available N, P and K also increased significantly with incorporation of FYM/green manure. Among the inorganic fertilizers 100% NPK maintained the available nutrient level as it was found to be competent even more than 50% and 75% N through rice-straw residues. Incorporation of inorganic fertilizers was considered important but with even application of recommended dose together with organic source to sustain the soil productivity and fertility.

Nyarko (2012) reviewed the causes and effects of soil acidity and the approaches used to ameliorate acid soils for sustained crop production in Ghana. It was reported that application of lime, organic materials, the use of acid tolerant crops and agroforestry are some of the management options adopted in curbing the menace associated with soil acidity. A combination of lime and organic materials, however was considered the most effective management option considering their availability and long-term effectiveness.

Opala *et al*. (2012) reported that addition of FYM had the effect of reducing both the exchangeable acidity and exchangeable Al. FYM was significantly able to reduced exchangeable acidity at 4 weeks after incubation, but only when it was applied @ 60 kg P ha^{-1} (26%) or in combination with Minjingu Phosphate Rock (31%). Although FYM gave lower exchangeable acidity and exchangeable Al levels than when no organic matter was applied at both sampling times, these differences were not statistically significant.

Singh *et al*. (2012) carried out a three-year field experiment to ascertain the role of zinc and sulphur on rice performance and nutrient dynamics in plant and soil with the following treatments, 4 levels of zinc; 0 kg ha^{-1}, 4 kg ha^{-1}, 5 kg ha^{-1} and 6 kg ha^{-1} and 4 levels of sulphur; 0 kg ha^{-1}, 20 kg ha^{-1}, 30 kg ha^{-1} and 40 kg ha^{-1} respectively. Results obtained reported that soil parameters like soil pH, EC, and organic carbon were not affected by the nutrient supplemented however the N, P, K, S and Zn were significantly affected by the addition of zinc and sulphur.

Srinivasaro *et al*. (2012) observed that application of FYM 10 Mg ha^{-1} + 100% NPK resulted in a higher C input and consequently built up a higher C stock. Higher profile of SOC stock (87.7 Mg ha^{-1}), C build up (35%) and C sequestration (15.4 Mg C ha^{-1}) was observed with the application of FYM 10 Mg ha^{-1} along with recommended dose of mineral fertilizer and these were positively correlated with cumulative C and well reflected in the sustainable yield index.

Jones *et al*. (2013) stated that soils with high CEC have high levels of exchangeable calcium, which can offset the pH increase caused by urea hydrolysis.

Kisinyo *et al*. (2013) reported that application of lime raised pH from an initial acidic condition by the displacement and replacement of acidic cations like Al^{3+}, H^{+} and Fe^{3+} ions by cations Ca^{2+} ions present in the liming material.

Osundwa *et al*. (2013) reported that soil pH and available P increased with the increase in the rate of lime addition.

Singh *et al*. (2013) carried out sampling experiment to study the soil micronutrient status, their relationship with soil physico-chemical properties and reported that the availability of micronutrients in soils were significantly influenced by soil properties viz. textural separates, organic carbon, $CaCO_3$, CEC and pH of the soils.

Thamaraiselvi *et al*. (2013) carried out an experiment to study the effect of FYM and inorganic fertilizers on soil properties and reported that combination of FYM and inorganic N and P fertilizers improved the chemical and physical properties. Combined application of FYM @ 15 t ha^{-1} and 100 kg P_2O_5 ha^{-1} increased the available P from 11.9 ppm to 38.1 ppm. They added that positive balances of soil N and P resulted from the combined application of FYM and inorganic N and P sources.

Sharma and Subehia (2014) reported that integration of inorganic fertilizers along with 50% N through FYM showed organic carbon increased from initial value of 6.0 to 8.66 g kg^{-1}, CEC from 11.5 to 14.6 cmol (p^{+}) kg^{-1} and available phosphorus from 21.9 to 75.2 kg ha^{-1} for the last twenty years while the status of available N and K declined over the years with all the treatments. He concluded that no addition of fertilizer or manure (control) led to significant reduction in available sulphur in comparison to sulphur treated plots.

Upadhaya and Vishwakatma (2014) reported that application of treatment 50% NPK + 50% N substituted through FYM and 100% NPK to wheat increased the soil organic carbon, available N, P_2O_5, K_2O, S and Zn, sustained soil pH, electrical conductivity and lowered bulk density. Maximum beneficial microorganisms, *viz*. fungi, bacteria, azotobacter, phosphorus solubilizing bacteria and actinomycetes were recorded highest with the integrated nutrient practices.

Verma *et al*. (2014) reported that organic carbon content of the soil, which was 2.9 g kg^{-1} in the initial sample, had increased in all the treatments and the highest value (4.0 g kg^{-1}) was recorded with 100% NPK + Zn + S + FYM.

Badole *et al*. (2015) reported a positive correlation between organic C with pH dependent acidity and total potential acidity in acidic soil of West Bengal.

Brar *et al*. (2015) found that soil organic carbon increased with the continuous application of FYM and inorganic fertilizers for 36 years among all the treatments. The SOC ranged from 3.08 g kg^{-1} to 5.20 g kg^{-1} in the 0-15 cm layer for different treatments. The SOC in 100% NPK + FYM increased to 5.20 g kg^{-1}, while 3.34 g kg^{-1} with application of 100% N, 3.71 g kg^{-1} with 100% NPK compared to non-treated control plot with 3.08 g kg^{-1}.

Shahid *et al*. (2015) observed that soil available N, P and K were significantly affected by different fertilization treatments where soil available N and P due to the long-term manure application along with chemical fertilizers which led to significantly higher values of soil available N as compared to other fertilization treatments. He also observed that unlike available N and P, available K was reported highest from NK + FYM followed by NPK + FYM treatment demonstrating the role of chemical fertilizers and organic manures in supplementation of K in the soil. He suggested that supplementation of K either through chemical fertilizers or organic manures over time may improve the soil available K supply.

Cheng *et al*. (2016) conducted a long-term field experiment to assess the changes in SOC content and C decomposition potential, total nitrogen (TN) content and nitrogen mineralisation potential under five treatments: PK, NPK, NPK + 6Mg ha^{-1} rice straw, NPK + 10 Mg ha^{-1} rice straw compost. They reported that in comparison with the NPK treatment the above treatments showed an increase in SOC and total nitrogen except for the PK treatment which showed a slight reduction in the SOC and total nitrogen. They concluded that application of rice straw helped in the reduction of methane production by 19% and confirmed that soil carbon decomposition potential and nitrogen mineralisation potential was highly correlated with SOC and total nitrogen contents.

Kalala *et al*. (2016) carried out a pot experiment with the different levels of zinc (0, 5 and 10 mg kg^{-1}) and sulphur (0.20 and 40 mg kg^{-1}) to establish optimum rates and critical concentration of both the nutrients in soil as well as in rice shoot. They reported that with the addition of zinc and sulphur the grain yield recorded significant increase in eight and three out of ten soils tested. They concluded the rates of 20 mg S and 5 mg Zn kg^{-1} soil was the optimum rates for soils with low S and Zn, respectively.

Kundu *et al*. (2016) observed increased and highest in soil microbial biomass carbon over the application of 100% NPK + FYM which varied from 221 to 435 mg kg^{-1} lowest recorded in control.

Majhi *et al*. (2016) studied the effect of continuous application of different chemical fertilizers and chemical on soil environment and reported that with continuous manuring SOC content in soil increased from 4.3 g kg^{-1} to 4.59 – 5.84 g kg^{-1} unfertilized treatments and decreased to 3.95 g kg^{-1} in unfertilized plots. Highest SOC was recorded in 100% NPK + FYM treatment. They also reported that combined application of S and Zn also improved the SOC content while Zn and B caused a fall in total organic carbon stock.

Rahman *et al*. (2016) conducted a study to determine the effect of organic amendments on CO_2 and emission to the atmosphere and C sequestration in soil. Among the five treatments control, cow dung (CD), poultry manure (PM), rice straw (RS) and soil-based test fertilizer (STB), application of CD, PM and while application of organic C through RS, CD and PM accounted for 10, 30 and 49% sequestration. They reported that PM was found to be efficient in increasing C and other nutrients in soils, and gave a higher grain yield of rice compared to RS and CD. Microbial activities were also reported to have had enhanced and favoured better root growth biomass with slight sequestration of SOC due to STB fertilization.

Fekadu *et al*. (2017) observed that application of organic and inorganic source of amendments significantly reduced soil exchangeable acidity and Al^{3+}.

They reported that exchangeable acidity and Al^{3+} were reduced significantly ($P<0.001$) at the 40 and 60 days of incubation with the application of 30 kg P ha^{-1} + 10 t lime ha^{-1} followed by 4 t FYM or compost ha^{-1}+ 15 kg P ha^{-1} + 10 t lime ha^{-1}. Organic sources like FYM and compost helped in neutralising the soil although it was at a slower rate as compared to lime.

Khan and Wani (2017) reported that integrated use of NPK and FYM recorded significantly higher build-up of soil organic carbon as compared to NPK fertilizer alone. The increase was about 31.2% over control. They reported that among the treatment's application of 50% NPK and 50% FYM recorded the highest organic carbon. The TOC in surface soil were also recorded with the application of 75% NPK + 25% FYM which was 40% greater than unfertilised control plot.

Meena and Mathur (2017) undertook a study to assess the status of micronutrients in relation to soil properties. They reported that soil available micronutrients Zn, Fe, Mn and Cu were positively correlated with soil Organic carbon, clay and CEC while pH, $CaCO_3$ and sand were negatively correlated.

Pant *et al*. (2017) reported that application of 100% NPK + FYM @ 10 t ha^{-1} increased the soil organic carbon content by 7.4 and 10.1% and it decreased by 39.2-44.6% and 36.8-49.1% in other NPK fertilizer treatments. In the absence of P, K, S and Zn addition, continuous cropping drastically reduced their availability in soil over the years. Physical properties were improved with the integrated use of fertilizers and manures. Active pools of soil organic carbon like TOC, MBC were recorded to be three time more than control and fertilizers treated plots.

Paul *et al.* (2017) conducted a field experiment on the influence of organic matter vis-a-vis humic acid on nutrient availability and its impact on rice-mustard cropping sequence under old alluvial zone of India. The results reported from the experiment were that at panicle initiation and branching stages of both the crops, available P, K and S recorded the highest values thereafter gradually declining. The FYM extracted humic acid resulted highest availability of P, K and S, whereas commercial humic acid enhanced the content of K in rice, which signified uptake of nutrients within plants resulting in enriched yields as well.

Kumari *et al*. (2017) reported that integrated nutrient management through inorganic and organic source proved to have a beneficial effect on the soil fertility status. Organic carbon build-up and increase of available N, P_2O_5, K_2O from the initial values. Similarly, available S and DTPA- Zn increased gradually due to long-term integrated nutrient management practices. It was reported that application of 50% NPK and 25% N of RDF to rice through organics either with FYM/green manure/wheat straw proved to increase the soil nutrient status significantly as compared to the sole application of inorganic fertilizers alone.

Tamado and Mitiku (2017) reported that application of FYM in combination with different levels of recommended rates of inorganic N and P significantly improved most of the soil physico-chemical properties. The application of 5 t ha^{-1} FYM + 75% N and 5 t ha^{-1} FYM + 75% P was found to be superior and increased the SOC content by 36 and 44.6%, available P by 70.5 and 78.2%, available K by 42.5 and 26.3% over the application of 100% recommended rates of inorganic N and P only (*i.e*., 100% N and 100% P) for the crop varieties.

Warjri *et al*. (2017) conducted an investigation to monitor the effect of the recommended dose of N, P, K fertilizers along with FYM, Zn, and S as a treatment combination. They reported that highest amount of Zn and S uptake is recorded in treatment combination which had the recommended doses of N, P, K fertilizers along with FYM and higher dose of S at 40 kg ha^{-1} and Zn at 50 kg

ha^{-1} treated plots over that of control and other treatments. It was confirmed that the dry matter yield and the uptake of nutrients by rice straw increased due to higher accumulation of nutrients in the crop. It was also reported that the amount of Zn and S taken up by the grain are comparatively more than that of straw of rice crop.

Goswami and Pandey (2018) reported that soil pH in post-harvest soil varied from 7.6 to 8.1. Soil treated with NPK + FYM recorded comparatively lower value of pH (7.6) while on the other hand higher pH were recorded with sole inorganic fertilizers.

Nemera *et al*. (2018) reported that organic manure and inorganic fertilizer combination application enhanced the soil organic and total nitrogen (0.98 and 0.081%), higher in exchangeable calcium (0.98) and Magnesium, sodium and potassium were (3.6, 0.46 and 12) respectively.

Singh *et al*. (2018) conducted an experiment to study the effect of organic manures on soil properties and reported that organic manures serve as a reservoir for cations such as calcium (Ca), magnesium (Mg), potassium (K) and ammonium (NH_4^+), which are readily exchangeable with soil particles.

Aziz *et al*. (2019) conducted an experiment with three levels of recommended dose of inorganic fertilizers (50, 75, 100%), three levels of organic manures (control, FYM @ 10 t ha^{-1} and Dalweed 10 t ha^{-1}) and two levels of biofertilizers (control and dual inoculation with Rhizobium+PSB). He reported that organic manures enhanced the soil physical properties and chemical properties of soil significantly like soil pH, EC, CEC with the exception of bulk density. He concluded that among organic manures FYM (10 t ha^{-1}) was found superior over Dalweed (10 t ha^{-1}).

Dhiman *et al*. (2019) reported that soil microbial biomass varied from 178 mg kg^{-1} in 100% N plot to 683 mg kg^{-1} in 100% NPK + FYM plots.

Application of NPK fertilizers either alone or in combination with organics/lime increased the microbial biomass carbon significantly over control. It was observed that treatment 100% NPK + FYM recorded the highest soil microbial biomass carbon which was followed by 100% NPK + Lime, 100% NPK + HW (hand weeding) while 100% N recorded the lowest.

Sireesha *et al*. (2019) reported that application of 100% RD of NPK + FYM @ 5 t ha^{-1} effectively increased and enhanced the build-up of N, P_2O_5, K_2O and organic carbon content in the soil. It was reported that organic source FYM @ 10 t ha^{-1} recorded the highest soil available micronutrients Zn, Fe, Mn and Cu and 100% RD of NPK + FYM @ 5 t ha^{-1} was also observed to be par with it.

Moe *et al*. (2019) carried out a two-year field experiment with the following six treatments: N_0 (no N fertilizer), 50% CF (chemical fertilizer), 100% CF, 50% CF+ 50% EMN (organic manures as estimated mineralizable N), Poultry manure (PM), Cow manure (CM), Compost (CP). They concluded that continuous application of $CF_{50}CM_{50}$ (total N<4%) and $CF_{50}CP_{50}$ (total N<4%) led to increased NPK availability and higher yields than those of CF_{100} treatment. Higher N availability each year was also recorded with the organic manure treatments leading to a reduced reliance and usage of CF.

Kumar *et al*. (2019) observed that integrated use of inorganic fertilizers and organic manure brings in more MBC in soil compared to inorganic fertilizer application alone. It was reported that soil basal respiration was significantly higher in treatment T_8 (100% NPK + Vermicompost @ 2 t ha^{-1} + PSB @ 8 kg ha^{-1}) recording 1.67 µg CO_2-C g^{-1} h^{-1} compared to 0.92 µg CO_2-C g^{-1} h^{-1} recorded from T_1 which had only inorganic fertilizer farmers' practice 100:74:0 kg ha^{-1} N:P: K.

Shahane *et al*. (2019) reported that soil DTPA-extractable Zn showed an increased in soil Zn status due to Zn fertilization indicating a positive effect on soil Zn content with application. He reported that zinc should be incorporated together with primary nutrient fertilizers for increasing the soil Zn concentration and eventually enhancing the crop yield.

Verma *et al*. (2019) found that highest soil microbial carbon was recorded in INM plots (363.7 ppm) which was significantly higher over control and at par with the treatments FYM alone, 100% NPK + Lime and 100% NPK. Low values of SMBC were observed in plots which received imbalanced fertilization and continuous mining of nutrients as in control.

Dhamak *et al*. (2020) reported that when chemical fertilizers were integrated together with FYM and other organic manures it recorded a high total organic carbon content as compared to chemical fertilizers alone where the values ranged from 15.50 to 18.70 g kg^{-1} in 0-15 cm soil depth.

Diwale *et al*. (2020) carried out a field experiment to study the impact of different manures on soil properties and yield of rice with four sources of manure i.e., FYM, poultry manure, vermicompost and goat manure and three levels of manure i.e., @ 2.5, 5.0, 7.5 t ha^{-1} with absolute one control. It was reported that application of poultry manure performed the best as compared to the other manures while level of manure @ 7.5 t ha^{-1} proved to have recorded the highest in terms of soil properties and crop yield as compared to the other levels.

Ao and Sharma (2020) reported the effect on lime on soil acidity components and confirmed that lime application significantly decreased exchangeable H^+, Al^{3+} and total potential acidity of post-harvest soil during both the years of experimentation. Application of ¼ lime @ LR decreased the mean exchangeable H^+ and Al^{3+} and total potential acidity by 37.9%, 8.3% and 11.3% respectively over control treatment.

Patra *et al*. (2020) revealed that application of biofertilizers and enriched compost had positive impact on plant accessible nitrogen, phosphorus and potassium in soil as compared to inorganic fertilizers. Also, soil organic matter content increased considerably by these treatments.

Begum *et al*. (2021) reported that nitrogen fertilization (120 and 140%) significantly increased the TOC and labile C pools when compared to control 100% and the lower rates 60 and 80%. It also increased MBC, C pool and lability that indicated an improvement of efficient soil biological activities in such system. The soil basal respiration rates increased significantly with 120% N fertilization by 10% and 13% in comparison with 60% N and 80% of N fertilization.

Debnath *et al*. (2021) reported a correlation coefficient study on soil total potential acidity and pH-dependent acidity and showed that soil organic carbon (SOC) of the different land use types was significant positively and highly correlated with pHDA ($r=0.552$, $P<0.05$) and TPA ($r=0.322$, $P<0.05$).

Gadisa and Wakgari (2021) reported that exchangeable acidity and Al were found to decreased in the soil due to the integrated use of organic manure and inorganic nitrogen fertilizers. The finding exhibited that exchangeable aluminium decreased by about 11.79, 14.62 and 26.08 % while exchangeable acidity decreased by about 16.63, 17.71 and 24.73% respectively by the application of 2.5, 5and 7.5 t ha^{-1} of vermicompost over control.

Ghosh *et al*. (2021) reported that application of organic manures like rice straw, FYM and vermicompost increased the total organic carbon of the soil. The increase was about 79% greater than the initial TOC of the soil.

Jena and Pattanayak (2021) reported that organic carbon stock and build up was higher in the integrated treatments of NPK and FYM/VC, biofertilizers and lime at both surface and sub-surface soil. Sole use of NPK resulted in lower amount of SOC sequestration.

Raut *et al*. (2021) studied the effect of different nutrient management practices and reported that soil organic carbon showed an improvement in its status as compared to initial. The nitrogen, phosphorus status was found significantly higher with T_5 receiving 100% RDN through poultry manure (PM) after harvest while the highest available potassium was received from T_{12} receiving equal integration of inorganics and poultry manure along with rhizobium and PSB inoculations. The available micronutrient was also found to be more than the sufficiency level in the treatment receiving application of 100% RDN through poultry manure.

Bilong *et al*. (2022) reported that application of organic manures improved soil physical and chemical properties of soil. It improved soil pH, OM, total N, available P, CEC and exchangeable cation like (K, Ca and Mg) as compared to control. However, the application of inorganic fertilizers alone decreased the physico-chemical properties of the soil. He reported that the application of fresh biomass and poultry manure solely or in mixed manner increased the soil pH, OM, total N, available P, CEC, exchangeable K, Ca and Mg in the range from 13 to 23%, 108 to 188%, 92 to 159%, 68 to 188%, 33 to 89%, 140 to 270% and 79 to 249%, respectively as compared to the control.

Singh *et al*. (2022) recorded the highest content of SMBC under FYM 20 t ha^{-1} (392.5 mg kg^{-1}) which was followed by 100% NPK + FYM 10 t ha^{-1} (355.50 mg kg^{-1}). Application of 100% NPK + FYM 10 t ha^{-1} and 100% NPK (N-FYM) showed significant increase in the content of SMBC by 34.91 and 36.63% over 100% NPK alone. He suggested that use of FYM alone or in combination with NPK significantly increased the soil microbial biomass carbon.

Song *et al*. (2022) explored the effects of organic fertilizer substitution on rice yield and paddy soil physico-chemical properties and bacterial community structure. They reported that replacing chemical fertilizers can reduce soil acidification, increase soil organic matter content, nutrient contents, and enzyme activities, improve soil physico-chemical properties and microbial community, and enhance soil metabolism.

Singh *et al*. (2023) carried out a review on acid soils' nutrient management in Manipur and reported that it will require a comprehensive approach that addresses the soil acidity, nutrient deficiencies and environmental sustainability. They recommended combination of soil testing, lime application, organic matter incorporation and INM practices to optimize crop yield and promote sustainability of acid soils.

Yu *et al*. (2023) results suggested combined application of organic-inorganic fertilizers could alleviate soil acidification while improving the soil CEC. In addition, they reported that it increased total phosphorus, total potassium, available phosphorus, and available potassium by 6.65-16.9%, 3.176-10.9%, 5.53-28.7% and 2.6-12% ($P<0.05$), respectively. They suggested the replacement ratios of chemical fertilizer with 25-50% cow manure are the most effective practices to improve yield and soil fertility.

Kumari *et al*. (2024) observed the highest SOC (1.18%) content and microbial biomass C (MBC: 618.40 mg kg^{-1}) with application of 15 Mg FYM + 150 kg N + 30 kg P_2O_5 ha^{-1}. He reported that integrated application of fertilizers with FYM had more beneficial impacts than sole organic manures on SOC, DOC, MBC content, DHA.

2.4 Effect of soil fertility management on economics in direct seeded rice

Baishya *et al*. (2015) found that the gross return and net return (₹ 76416 and ₹ 476161) were markedly higher with 125% CDF (chemical fertilizer dose) + 2.5 t poultry manure ha^{-1} closely followed by 100% CDF + 2.5 t poultry manure ha^{-1}, 75% CDF + 2.5 t poultry manure ha^{-1}. However, higher benefit cost ratio (2.76) was observed with 125% CDF + Sesbania green manure ha^{-1} and 75% CDF + 2.5 t poultry manure ha^{-1}. The highest profitability (₹ 366.28 day^{-1} ha^{-1}) was recorded with 125% CDF + 2.5 t poultry manure ha^{-1}. He reported that the trend studied in the study in economic return was mainly due to the treatment effect on the grain and stover yield of rice.

Tiwari *et al*. (2017) carried out a field investigation to assess the impact of INM on soil properties and economics of the rice yield and obtained maximum gross return (92,093 ₹ ha^{-1}), maximum net return (66, 420 ₹ ha^{-1}) and B:C ratio (2.59) in the treatment where integrated nutrients was applied.

Mandal *et al*. (2018) found that the highest cost of cultivation was recorded in treatment T_8 where 25% RDN from chemical fertilizer + 75% RDN from mustard oil cake was applied (68,637 ₹ ha^{-1}) followed by application of 50% RDN from chemical fertilizer + 50% RDN from mustard oil cake (59550 ₹ ha^{-1}). In the treatment of only chemical nitrogen application, it was the lowest (41,378 ₹ ha^{-1}) cost of cultivation rate. The result indicated that, combination of organic and inorganic nutrients became costlier than that of sole chemical fertilizer. The highest rupee per rupee invested (2.25) was found in 100% RDN from chemical fertilizer. However, it was at par with 75% RDN from chemical fertilizer + 25% RDN from dhaincha green manure (2.23).

Singh *et al*. (2019) investigated the productivity, sustainability and profitability of rice-wheat system with eight treatments *viz*., N, NP, NPK, NPK + FYM and control. Results revealed that application of NPK + FYM gave the highest and sustainable yields, enhanced soil organic carbon content and highest net return of the crop.

Rama *et al*. (2020) reported that benefit cost ratio was found higher in 100% RDN and it was followed by 75% RDN + 25% RDN through FYM. Cost of cultivation increased with the use of organic manures that is 25% RDN + 25% RDN through vermicompost + 50% N through FYM while the lowest was recorded with control T_1 as it had no fertilizer application. The highest gross and net returns were observed highest when the crop was supplied with 75% RDN + 25% RDN through vermicompost (VC) and it was statistically at par with 75% RDN + 25% RDN through FYM, then followed by 100% RDN, 50% RDN + 50% N through FYM and 50% RDN + 25% N through vermicompost (VC) + 25% N through FYM.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study entitled "Soil fertility management under direct seeded rice (*Oryza sativa* L.) in the acidic soil of Nagaland" was conducted in the experimental farm of School of Agricultural Sciences, Nagaland University, Medziphema Campus during the *kharif* seasons, 2021 and 2022. Detailed climatic, geographical and edaphic conditions under which the experiment was carried out and the materials used, analytical techniques employed for analysis of soil and plant material to meet the required objectives of the study are well documented in this chapter.

3.1 Experimental site

The farm is situated at an altitude of about 310 m above mean sea level (MSL) with geographical location at 25°45'43" latitude and 95°53'04" longitude.

3.2 Climatic condition

The experimental farm lies in humid and sub-tropical climate with an average rainfall ranging from 2000-2500 mm annually. The mean temperature ranges from 21-32℃ during summer and rarely goes below 8℃ in winter due to high atmospheric humidity. Monthly meteorological data during the experimentation period are given in table 3.1 and depicted in fig 3.1

3.3. Characteristics of the experimental soil

The soil of the experimental plot was characterized by well drained and sandy clay loam in texture. The composite soil sample was collected from experimental field (0-15 cm depth) before initiating the experiment. The collected soil samples were air dried, crushed, sieved to pass through 2mm sieve. The processed samples were used for analysis of mechanical, physio-chemical and fresh samples for biological parameters following standard analytical procedures. The result has been presented in table 3.2.

Table 3.1. Monthly meteorological data during the period of investigation (June- November)

Months	**Temperature(°C)**		**Relative Humidity (%)**		**Rainfall (mm)**
	Max	**Min**	**Max**	**Min**	
2021					
June	33.1	24.5	91	69	158.8
July	33.2	24.8	91	72	287.1
August	32.7	24.4	93	70	176.0
September	33.0	23.6	93	68	117.5
October	31.4	20.5	94	63	130.0
November	27.8	14.3	95	51	8.5
2022					
June	32.0	23.9	95	72	160.8
July	33.6	24.3	92	69	375.8
August	33.3	24.1	94	70	261.8
September	33.0	23.8	91	69	161.2
October	30.5	21.3	94	69	94.8
November	28.4	14.8	96	58	0.0

*Source: ICAR Regional Research Centre, Jharnapani, Nagaland

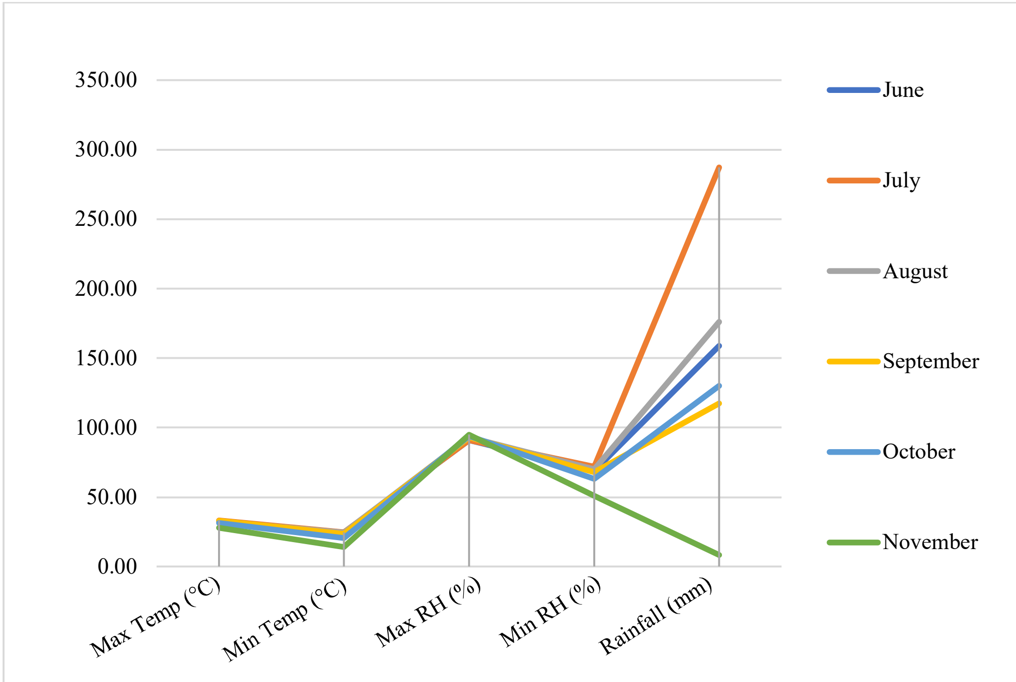


Fig 3.1: Monthly meteorological data during the period of investigation (2021)

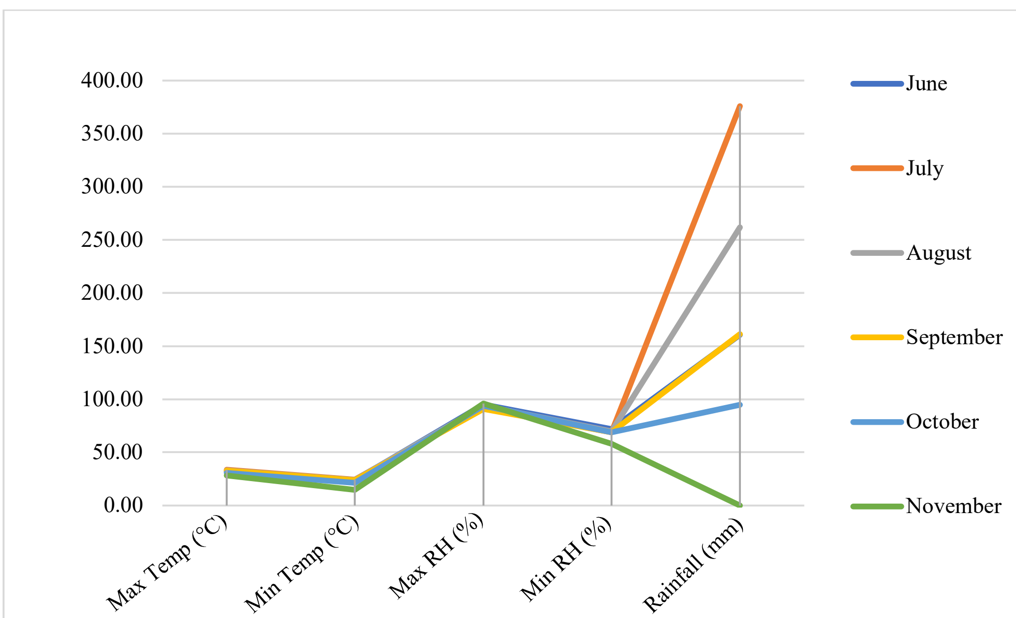


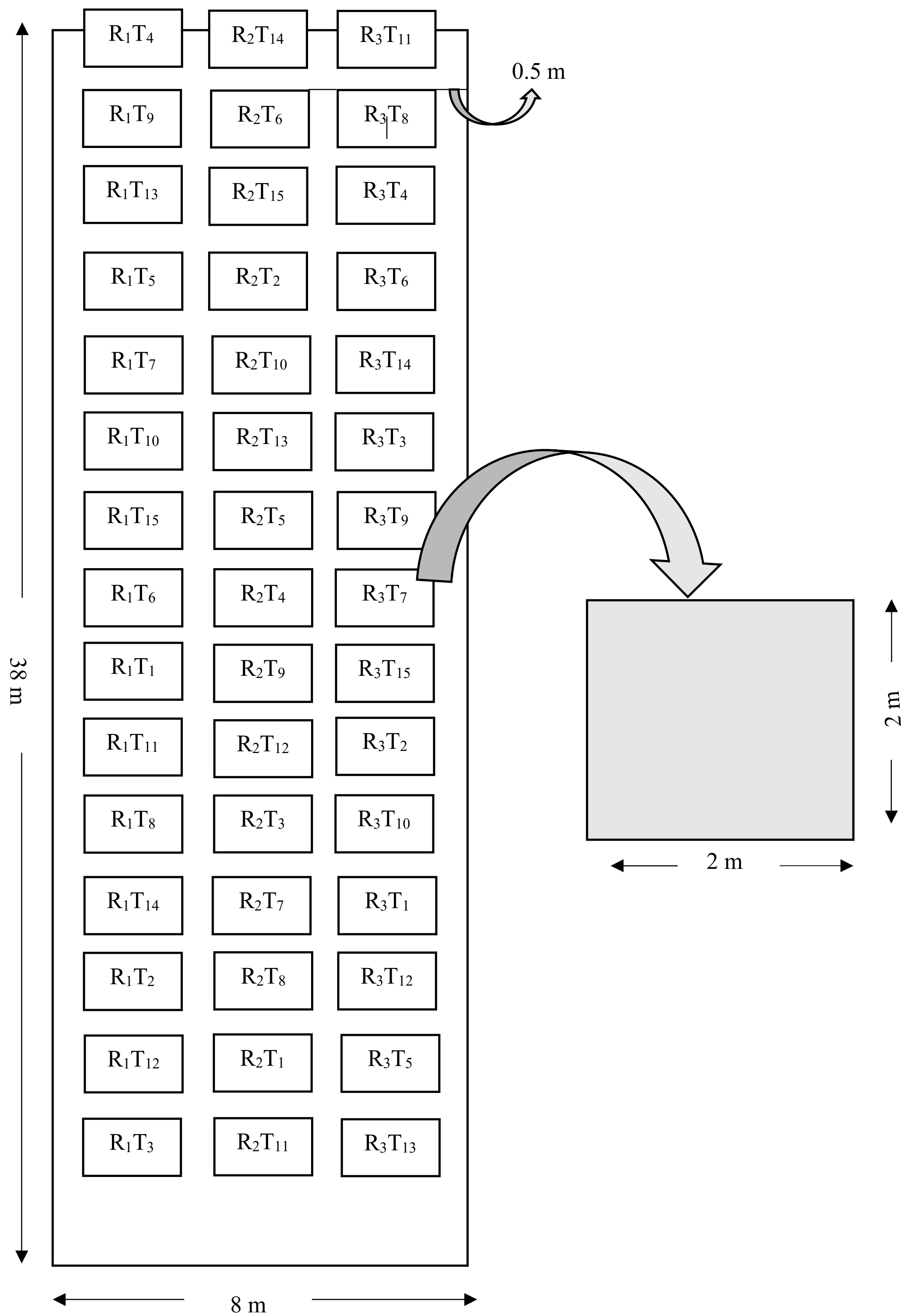
Fig 3.2: Monthly meteorological data during the period of investigation (2022)

Table 3.2: Initial soil status of the experimental plot

Sl. No.	Soil parameters	Methods	Values	
			2021	2022
1.	Soil pH	Glass electrode pH meter method (Jackson 1973)	4.25	4.41
2.	EC (dS m^{-1})	Conductivity bridge (Richards, 1954)	0.04	0.03
3.	Organic carbon (g kg^{-1})	Wet oxidation method, Walkley and Black (1934)	15.2	17.3
4.	Total organic carbon (g kg^{-1})	Synder and Trofymow (1984)	23.50	25.68
5.	Bulk density (g cm^{-3})	Pycnometer method (Dakshinamurti and Gupta, 1968)	1.41	1.45
6.	CEC [cmol (p+) kg^{-1}]	NH_3 OAc, pH 7.0 distillation method (Chapman, 1965)	10.57	12.60
7.	Available N (kg ha^{-1})	Alkaline permanganate method (Subbiah and Asija, 1965)	256.42	264.86
8.	Available P (kg ha^{-1})	Bray and Kurtz method (1945)	9.05	12.42
9.	Available K (kg ha^{-1})	Ammonium acetate method (Jackson, 1973)	96.60	106.33
10.	Available S (kg ha^{-1})	0.15% $CaCl_2$ (William and Steinbergs, 1959)	14.26	14.60
11.	Exchangeable Ca [cmol (p+) kg^{-1}]	Versenate method (Black, 1965)	1.24	1.23
12.	Available Zn (mg kg^{-1})	DTPA-$Cacl_2$-TEA extraction method (Lindsay and Norwell, 1978)	1.10	1.18
13.	Available Fe (mg kg^{-1})		32.54	33.25

14.	Available M n (mg kg^{-1})	DTPA-$Cacl_2$-TEA extraction method (Lindsay and Norwell, 1978)	12.48	12.74
15.	Available Cu (mg kg^{-1})		1.60	1.59
16.	Exchangeable acidity [cmol (p+) kg^{-1}]	1 *N* KCl solution titrated against 0.1 *N* NaOH solution (Baruah and Barthakur, 1997)	3.83	3.64
17.	Exchangeable Al^{3+} [cmol (p+) kg^{-1}]	NaF solution (4%) in 1 *N* KCL (Baruah and Barthakur, 1997)	3.00	2.84
18.	Total potential acidity [cmol (p+) kg^{-1}]	$Bacl_2$ – triethanolamine extract buffered at pH 8.0-8.2 (Baruah and Barthakur, 1997)	12.70	12.60
19.	pH- Dependent acidity [cmol (p+) kg^{-1}]	pH-dependent acidity = Total potential acidity – Exchangeable acidity (Baruah and Barthakur, 1997)	8.87	8.96
20.	Soil microbial biomass carbon (μ g g^{-1} soil)	Fumigation extraction method (Vance *et al.*, 1987)	175.78	216.86
21.	Soil basal respiration (μg CO_2-C g^{-1} hr^{-1})	Alkali entrapment method (Anderson, 1982)	9.90	10.17
22.	Mechanical analysis Sand (%) Silt (%) Clay (%)	International pipette method (Piper, 1966)	50.8 19.5 29.6	49.5 23.2 26.9
23.	Textural class		Sandy clay loam	

Fig 3.3. Layout of the experimental field in Randomised Block Design



3.4 Experimental details

3.4.1 Experimental layout

The experimental plot was laid out in a randomised block design with fifteen treatments replicated thrice. The experiment was conducted consecutively for two years (2021 and 2022) on the same site. Equal division of the site into three blocks while maintaining uniform size plots (2 m × 2 m) in each replication to accommodate all the treatments. A total of 45 plots were obtained from the site. The treatments were allotted randomly within the plots of each experimental block.

The details of the experimental field:

i.	Crop	: Rice (*Oryza sativa* L.)
ii.	Variety	: Bhalum 3
iii.	Experimental Design	: Randomised Block Design
iv.	Number of treatments	: 15
v.	Number of replications	: 3
vi.	Total no. of plots	: 45
vii.	Gross plot size	: 2×2 m^2
viii.	Spacing	: 20 cm× 10 cm
ix.	Plot to plot distance	: 0.5 m
x.	Block border	: 0.5 m
xi.	Experimental area	: 38×8 m^2
xii.	Treatment details**:**	

T_1 = Control

T_2 = 100% NPK

T_3 = 50% NPK

T_4 = SSNM (109:30:46 NPK)

T_5 = 100% NPK + Zn

T_6 = 100% NPK + S

T_7 = 100% NPK +Zn + S

T_8 = 100% NPK +Zn +S + FYM @ 5t ha^{-1}

T_9 =100% NPK + Liming @LR

T_{10} = 50% NPK + Azospirillium

T_{11} = 50% NPK + 50% N-FYM

T_{12} = 50% NPK + 50% N- VC

T_{13} = 50% NPK + 25% N-FYM + 25% N-VC

T_{14} = FYM @ 10 t ha^{-1}

T_{15} = FYM @ 10 t ha^{-1} + Liming @ LR

3.5 Cultivation details

3.5.1 Selection and preparation of field

A rectangular plot having uniform soil fertility and even topography was selected for the field experiment. Land preparation was carried out 1-2 month before sowing by ploughing with a tractor drawn plough followed by a rotavator to break the hard pans and clods to make it into a fine seedbed. All the weeds and stubbles were removed and then the field was levelled and laid according to the layout plan.

3.5.2 Fertilizer and manures application

Fertilizers and manures were applied according to the treatment requirements which were calculated and given to each plot. Recommended dose of N, P and K @ 100 kg ha^{-1}, 40 kg ha^{-1} and 60 kg ha^{-1} respectively were applied. 50 kg ha^{-1}, 20 kg ha^{-1} and 30 kg ha^{-1} NPK were taken as 50% of the recommended dose of fertilizer, respectively. Nitrogen was applied in three split doses 50% at the time of sowing using DAP, 25% at tillering and 25% at panicle initiation through fertilizer urea. Phosphorus was satisfied with DAP as source and potassium through MOP respectively, applied at the time of sowing. Zinc and sulphur were applied at the time of sowing with zinc sulphate heptahydrate (ZnSO4. $7H_2O$ 21% Zn) @10 kg ha^{-1} and gypsum (CaSO4.$2H_2O$ 18.6% S) @ 20 kg ha^{-1}. Liming @ LR treatments were used with lime ($CaCO_3$) using furrow application prior to 30 days before sowing. Well decomposed FYM were uniformly broadcasted in the required plot with the required quantity according to treatments prior to 30 days before sowing. Vermicompost was also applied to the specific treatment plots at the time of sowing with proper soil incorporation. Biofertilizer Azospirillum @ 600 g ha^{-1} was used for the specific treatments which were properly incorporated with the soil at the time of sowing.

3.5.3 Seed rate and sowing

Healthy and bold seeds of rice were sown directly to their respective plots by maintaining a spacing of 20 cm row to row and 10 cm plant to plant with a seed rate of 80 kg ha^{-1}. The sowing was done on the forth night of June.

3.5.4 Thinning and gap filling

The thinning operation was carried out after about one month of sowing to maintain a uniform plant to plant spacing and at the same time gap filling was done in the required plots.

3.5.5 Weed control

The first-hand weeding was done 15 DAS with the help of khurpi and local hoe and later maintained 15-day intervals. This cultural practice was carried out because during the seedling stage, the crop- weed competition was very high especially for direct seeded rice.

3.5.6 Pest control

Pests specifically termites and gundhi bugs were controlled using Chloropyriphos and Malathion solution as it affected crops during seedling and milking stages.

3.5.7 Harvesting

The crop was harvested after it attained the physiological maturity of grain in respective plots. The crop was harvested in the initial week of October when 85% of panicles had about 85% ripened spikelets and upper portion of the spikelets look straw coloured. The grains were hard enough having less than 20% moisture. The straw was cut from the ground level with the help of sickle, after which the harvested crop from their respective plots was carefully bundled, tagged and brought to the threshing floor for harvesting.

3.5.8 Threshing

Threshing was done manually plot wise and the grain yield was recorded after winnowing and cleaning. Grain yield, thus obtained from each plot were recorded as kg ha^{-1}. The straw was sun dried and later weighed in unit kg ha^{-1}.

3.6 Observations to be recorded

3.6.1 Growth parameters

3.6.1.1 Plant height (cm)

Five plants from each plot were randomly selected and tagged for recording the plant height at different growth stages. The plant height was measured in centimetres (cm) from the ground level to the top of the plants at 45, 90 DAS and at harvest. The average height of the plant for each treatment was calculated.

3.6.1.2 Number of tillers plant^{-1}

The number of tillers plant^{-1} was recorded from each plot at 45 and 90 DAS. The average number of tillers plant^{-1} was calculated for each treatment and recorded.

3.6.1.3 Crop growth rate (g m^{-2} day^{-1})

It represents dry weight gained by a crop in a unit area at a given time. It is expressed in g m^{-2} day^{-1}. The crop growth rate (CGR) at 45, 90 DAS was calculated by using the dry matter accumulation (g) of plants for each plot at successive growth with the following formula.

$$CGR = \frac{w_2 - w_1}{(t_2 - t_1)\,S}$$

Where,

W_1 and W_2 are the dry weight of the plants at time t_1 and t_2 respectively.

S is land area (m^2) over which dry matter was recorded.

3.6.1.4 Relative growth rate (g g^{-1} day^{-1})

The relative growth rate of crops at time instant (t) is defined as the increase of plant material per unit weight per unit time. It is expressed in g g^{-1} day^{-1}. Relative growth rate (RGR) at 45 and 90 DAS was calculated using the same recorded data of dry matter accumulation of plants with the help of the following formula.

$$RGR = \frac{\ln w_2 - \ln w_1}{(t_2 - t_1)}$$

Where,

W_1 and W_2 are the dry matter produced in a gram (g) of existing dry matter in a day at time t_1 and t_2 respectively.

3.6.2 Yield attributes

3.6.2.1 Number of panicles m^{-2}

The number of panicles m^{-2} were counted from each plot and recorded respectively.

3.6.2.2 Length of panicle (cm)

The panicle length per plant was recorded from the tagged plants of each plot at the time of harvest. The length was measured from the neck nodes to the tip of the uppermost spikelets in centimetres. The average panicle length per plant for each treatment were calculated and recorded.

3.6.2.3 Number of grains $panicle^{-1}$

The number of grains $panicle^{-1}$ were counted from the tagged plants from each plot at the time of maturity and the average number of grains $panicle^{-1}$ was recorded for each treatment.

3.6.2.4 Number of filled grains $panicle^{-1}$

The number of filled grains $panicle^{-1}$ were counted from the number of grains $panicle^{-1}$ tagged plants. The average number was calculated and recorded.

3.6.2.5 Number of unfilled grains panicle^{-1}

The number of unfilled grains panicle^{-1} was calculated by subtracting number of filled grains panicle^{-1} from the number of grains panicle^{-1} respectively for each plot. The average number of unfilled grains panicle^{-1} was recorded for each treatment.

3.6.2.6 Test weight (g)

1000 bold grains were counted from the threshed and clean grains and their weight was precisely recorded by an electronic weighing balance for each treatment. The weight of these 1000 grains was taken in gram.

3.6.2.7 Grain yield (kg ha^{-1})

The grains obtained after harvesting was thoroughly sun dried and weight was taken to determine the grain yield in terms of kg ha^{-1}. The grains weight from each plot was recorded and later converted into kg ha^{-1} using the formula

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the grain per plot} \times 10000}{\text{Size of the plot (m}^2\text{)}}$$

3.6.2.8 Straw yield (kg ha^{-1}):

After harvesting the straw bundles was sun dried and collected from each of the plot and weight was taken separately to determine the straw yield in terms of kg ha^{-1}. The straw yield obtained from each plot was recorded and later converted into kg ha^{-1} using the formula.

$$\text{Straw yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the straw per plot} \times 10000}{\text{Size of the plot (m}^2\text{)}}$$

3.6.2.9 Harvest index (%):

Harvest index is the ratio of grain yield to biological yield. It can be expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Where biological is the total of grain yield and straw yield.

3.7 Plant analysis

The collected grain and straw from the designated plots were sun dried separately and put to oven for drying at 60-70°C to attain constant weight. The dried samples such as grain and straw were then grinded to powdered and stored in polythene bags with proper labelling for chemical analysis. The powdered grain and straw samples were analysed for N, P, K, S, Ca, Zn, Fe, Cu, and Mn content.

3.7.1 Nitrogen in grain and straw (%)

Half a gram powdered sample was digested with concentrated H_2SO_4 in the presence of digestion mixture ($CuSO_4$ + K_2SO_4) till the digest gave clear bluish colour. The digested sample was further diluted carefully with distilled water to known volume. Then a known volume of aliquot was transferred to distillation unit (Micro kjedahl – apparatus) and liberated ammonia was trapped in boric acid containing mixed indicator. Later it was titrated against standard 0.1 *N* H_2SO_4 and the amount of ammonia liberated was estimated in the form of nitrogen as per the procedure given by Black (1965).

3.7.2 Digestion of plant sample for P, K, S, Ca, Zn, Fe, Cu and Mn

Half a gram powdered sample was pre-digested with concentrated HNO_3 overnight. Further pre-digested sample was treated with di- acid (HNO_3: $HCLO_4$ in the ratio of 10:4) mixture and kept on the hot plate for digestion till colourless thread-like structures was obtained. After complete digestion precipitate was dissolved in 6 *N* HCL and transferred to the 100 ml volumetric flask through

Whatman No. 42 filter paper and finally the volume of extract was made to 100 ml with double distilled water and preserved for further analysis.

3.7.3 Phosphorus in grain and straw (%)

Phosphorus both in seed and stover was estimated by vanado-molybdate yellow colour method as outlined by Jackson (1973).

3.7.4 Potassium in grain and straw (%)

The aliquot after digestion for estimation of potassium was diluted to the desired level and were analysed using flame photometer as described by Chapman and Pratt (1961).

3.7.5 Sulphur in grain and straw (%)

Sulphur content was analysed with the aliquot from the digested sample, diluted to a desired level and determined turbimetrically as described for soil sulphur by William and Steinbergs (1959).

3.7.6 Calcium in grain and straw (%)

The calcium content in seed and stover was analysed with the digested aliquot and determined by versenate (EDTA) method (Prasad, 1998).

3.7.7 Micronutrients (Zn, Fe, Cu, Mn) in grain and straw (mg kg^{-1})

The aliquot obtained from the wet digestion was used for the estimation of Zn, Fe, Cu and Mn using AAS (Atomic Absorption Spectrophotometer) as described in the DTPA method (Lindsay and Norwell, 1978).

3.8 Nutrient uptake

The uptake of different nutrients was separately carried out in grain and straw samples thereby multiplying nutrient content in grain and straw samples with their corresponding yield data.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Yield (kg ha}^{-1}\text{)} \times \text{nutrient content (\%)}}{100}$$

For micronutrient uptake,

$$\text{Nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Yield (kg ha}^{-1}\text{)} \times \text{nutrient content (mg kg}^{-1}\text{)}}{1000}$$

3.9 Soil analysis

Soil samples were collected from a depth of 0-15 cm from each experimental plot after the harvest of the crop. Collected soil samples were dried in shade, grounded using mortar and pastel and sieved through 2 mm sieve and stored in polyethene bags with proper labelling for the further analysis of various parameters using standard protocol as mentioned below.

3.9.1 Mechanical analysis

The sand, silt and clay fractions of the soil samples were determined by the International Pipette method using 1*N* sodium hydroxide (NaOH) as dispersing agent Piper (1996). Hydrogen peroxide was used to dissolve the organic matter in soil. After obtaining the percentage of sand, silt and clay, textural classes were designated using the textural triangle.

3.9.2 Soil pH

Soil pH was determined in a soil: water (1: 2.5) ratio using a glass electrode pH meter Jackson (1973).

3.9.3 Electrical conductivity

A soil water suspension of ratio 1: 2.5 was prepared to determine the electrical conductivity of the soil using conductivity bridge at room temperature as described by Richards (1954). It is expressed in dSm^{-1}.

3.9.4 Bulk density

Bulk density was determined by Pycnometer method as described by Dakshinamurti and Gupta (1968). It is expressed in $g\ cm^{-3}$.

3.9.5 Organic carbon

Soil organic carbon was determined by wet oxidation method as outlined by Wakley and Black method (1934) and the result was expressed in (g kg^{-1}).

3.9.6 Total organic carbon

TOC was determined by wet oxidation method as described by Synder and Trofymow (1984). TOC was determined in 'Vario TOC analyser', that measures total carbon (TOC) and total inorganic carbon (TIC) for both solid and liquid samples by differential method (TOC=TC-TIC). IR detector was used in the instrument while determining TOC of the soil sample. 10-15 mg of the soil samples were injected into the combustion tube which was enriched with synthetic air (O_2). carbon in the sample was converted into CO_2 at 950°C in presence of catalyst (CuO_2). Carrier gas carries the CO_2 to the detector tube and thus TOC was determined. The % TOC was converted and expressed in g kg^{-1}.

3.9.7 Cation exchange capacity (CEC)

The cation exchange capacity (CEC) of the soil was determined by NH_3 distillation method Chapman (1965). It is expressed in cmol (p^+) kg^{-1}.

3.9.8 Available nitrogen

The available nitrogen was determined by alkaline potassium permanganate method suggested by Subbiah and Asija (1956) and the result was calculated in terms of kg ha^{-1}.

3.9.9 Available phosphorus

Available phosphorus was extracted with 0.03 *N* NH_4F in 0.025 *N* HCL solutions. The procedure is primarily meant for soils which are moderate to strongly acidic soils with pH around 5.5 or less and determined by Bray and Kurtz method (1945). Available phosphorus was expressed as P_2O_5 kg ha^{-1}.

3.9.10 Available potassium

The available potassium in soil was determined by flame photometer method using neutral ammonium acetate (pH 7.0). The potassium content in the extract was determined and expressed as available K_2O kg ha^{-1} as explained by Jackson (1973).

3.9.11 Available sulphur

The sulphate in the soil was extracted using monocalcium phosphate solution (500 ppm) and determined turbidimetrically using a spectrophotometer at 440 nm wavelength as described by Chensin and Yien, 1950. Available sulphur content in soil was expressed in kg ha^{-1}.

3.9.12 Exchangeable calcium

The exchangeable calcium was extracted with neutral normal ammonium acetate and determined by versenate method, where known volume of soil extract was titrated with standard 0.01 *N* versenate (EDTA) solution using murexide (ammonium purpurate) indicator in the presence of NaOH solution (Black, 1965).

3.9.13 Micronutrients (Available Zn, Fe, Cu and Mn)

Available Zn, Fe, Cu and Mn were determined using the DTPA-$Cacl_2$-TEA extraction method as outlined by Lindsay and Norwell, 1978. Diethylene triamine penta acetic (DTPA), a chelating agent, combines with free metal ions in solution and forms soluble complexes. Available Zn, Fe, Cu and Mn were expressed in mg kg^{-1}.

3.9.14 Exchangeable acidity

Exchangeable acidity was determined by using 1 *N* KCL solution and titrating against 0.1 *N* NaOH until pink colouration is obtained as mentioned by Baruah and Barthakur (1997).

3.9.15 Exchangeable Al^{3+}

Exchangeable Al^{3+} in soil was determined by adding 5 ml of NaF solution (4%) in 1 *N* KCL. This solution was then titrated against 0.1 *N* HCL until the pink colouration disappeared as described by Baruah and Barthakur (1997).

3.9.16 Total potential acidity

The total potential acidity of soil includes all the acidity components like the extractable acidity, non-exchangeable acidity, weak acidic carboxylic and phenolic hydroxyl groups of soil organic matter and partially neutralised hydroxyl Al polymers that could be present even in soils. The total potential acidity was determined by using $Bacl_2$ – triethanolamine extract buffered at pH 8.0-8.2 as described by Barauh and Barthakur (1997).

3.9.17 pH-dependent acidity

pH dependent acidity was determined by using the formula below as described by Baruah and Barthakur (1997).

pH-dependent acidity = Total potential acidity – Exchangeable acidity

3.9.18 Soil microbial biomass carbon

Microbial biomass carbon of soil was determined by using the fumigation-extraction method by (Vance *et al*., 1987). The fresh soil sample were placed in the 50 ml beakers and kept in vacuum desiccators for fumigation with chloroform for 24 hours. The fumigated soil samples were treated with K_2SO_4 and placed in the shaker for few minutes. The extracts were filtered and digested using H_2SO_4 and then titrated against 0.005 *N* ferrous ammonium sulphate. The microbial biomass carbon was calculated as the difference between the values obtained from fumigated and non-fumigated soil samples. MBC was calculated using the following formula:

MBC (μ g g^{-1} soil) = $EC_F - EC_{NF} / K_{EC}$

Where,

EC_F = total weight of extractable C in fumigated soil sample

EC_{NF} = total weight of extractable C in non- fumigated soil sample

K_{EC} = calibration factor ~ 0.38

3.9.19 Soil basal respiration

Soil respiration is determined by taking 50 g of soil in a desiccator beaker where 20 ml of 1 N NaOH taken in a test tube to be kept in the desiccator for a period of 7 days. The beakers are tightly sealed with the help of paraffin wax. After the required period the NaOH solution is titrated against 1 *N* HCl with a pinch of barium chloride until the milky pink colouration disappears. It is expressed in µg CO_2-C g^{-1} hr^{-1}. Alkali entrapment method (Anderson, 1982) was employed for determining soil respiration.

3.10 Economic analysis

Gross return, net return and benefit- cost ratio was worked out for various treatments at the end of the first crop and also at the end of the crop sequence on the basis of input costs and output prices. Economics of the various treatments were worked out as per the existing market prices.

3.10.1 Cost of cultivation (₹ ha^{-1})

The cost of cultivation was calculated as per item wise cost incurred in each treatment.

3.10.2 Gross return (₹ ha^{-1})

Gross return in rupee per hectare on the basis of current price of the produce was worked out by multiplying grain and straw yield separately under various treatments. The money value for grain and straw was added together in order to achieve gross return.

3.10.3 Net return (₹ ha^{-1})

Net return from each treatment was calculated by subtracting the cost of cultivation from the gross return.

Net return = Gross return – Cost of cultivation

3.10.4 Benefit: Cost ratio

The benefit: cost ratio was worked out on the basis of net return and cost of cultivation by using the following formula:

$$\text{B: C ratio} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

3.11 Statistical analysis

The data related to each character were analysed statistically by applying the techniques of variance and the significance of different source of variation was tested by ‘F’ test (Cochran and Cox, 1962).

Plate 1: General view of the experimental field

Plate 2: Land preparation and plot layout of the field

Plate 3: Crop at seedling stage

Plate 4: Crop at tillering stage

Plate 5: Crop at flowering stage

Plate 6: Crop at grain filling stage

Plate 7: Crop at grain maturity stage

Plate 8: Harvesting of the crop

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

A research investigation has been undertaken to assess the "Soil fertility management under direct seeded rice (*Oryza sativa* L.) in the acidic soil of Nagaland" which was carried out during the *kharif* season of 2021 and 2022. The observations recorded during both the years have been recorded systematically and statistically analyzed in order to assess their degree of variance due to diverse treatments. The results have been presented through relevant tables and figures compiled together in keeping with evidences and reasonings based on different experiments and literature available related to the topic of investigation to obtain a well-grounded, logical conclusion for scientific and practical utility.

4.1 Effect of soil fertility management on growth and yield attributes in direct seeded rice.

Growth is a permanent change which increases the size of the plant. It is an essential property of plants in which nutrients are accumulated for cell division and enlargement, a fundamental characteristic for life forms, helps plants compete with each other and also protect their important organs. Plants require an adequate amount of nutrients for proper growth and the quality and quantity of nutrients affect the plant growth. Development is a sum total growth and differentiation and plants cannot grow if the plants do not undergo grow and differentiate. Different growth attributes like plant height, number of tillers plant^{-1}, crop growth rate and relative growth rate were recorded at successive stages of crop i.e., 45, 90 and at harvest are explained.

Yield is a result of the vegetive growth of the crop. The available nutrient present in the soil helped the plant to take up the nutrients made available through inorganic and organic fertilizers and assisted in development of yield attributes like length of panicle, number of panicle m^{-2}, number of filled and unfilled grains panicle^{-1}, test weight, grain yield, straw yield and harvest index respectively.

4.1.1 Plant height (cm)

Data pertaining to plant height (cm) of rice crop at different stages of plant growth at 45, 90 DAS and harvest are presented in table 4.1 and graphically illustrated in fig 4.1.

The values given in the table 4.1 evidently showed that the plant height had visible difference with the application of different treatments. It was observed that plant height increased from 43.61 to 72.08 cm, 70.23 to 111.41 cm and 86.01 to 134.46 cm at 45, 90 DAS and harvest, respectively. The significant increase in the plant height can be attributed to the application of nutrients required for the growth and development of the plant at different stages of crop development. Application of T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) proved to have significantly enhanced plant height over the control (T_1) at all the stages of plant growth. It did not only have a significant difference with control (T_1) but also demonstrated to have been significantly higher over all the other treatments which gives an explanation that although sole balanced inorganic fertilizer application enhanced the plant growth but in combination with organic manure FYM it had superlative effect on the plant height. FYM has a significant role in enhancing soil health, quality and biological properties of soil. Better plant height may also be attributed to the fact to addition of NPK with more nutrients like sulphur and micronutrient Zn resulted in higher availability of nutrients in the soil for plant nourishment and further, FYM organic source which encourages slow release and continuous availability of nutrients promoted cell division, elongation as well as various metabolic processes which ultimately enhanced the plant height of the crop. The above results are in conformity with the findings of Murthy (2012) and Singh *et al*. (2018). Findings from Singh *et al*. (2018) and Barik *et al*. (2006) also reiterated the integration of inorganic fertilizers along with organic sources like FYM improves soil environment for

Table 4.1: Effect of soil fertility management on plant height in direct seeded rice

Treatments	Plant height (cm)								
	45 DAS			90 DAS			At harvest		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	42.72	44.51	43.61	69.62	70.83	70.23	85.37	86.65	86.01
T_2- 100% NPK	52.55	55.53	54.04	83.87	87.11	85.49	95.93	101.83	98.88
T_3- 50% NPK	49.50	53.83	51.67	81.49	84.93	83.21	96.30	98.15	97.23
T_4- SSNM (109:30:46 NPK)	61.60	65.28	63.44	96.88	99.38	98.13	110.23	122.93	116.58
T_5- 100% NPK + Zn	62.14	62.61	62.37	99.16	102.32	100.74	119.67	126.92	123.29
T_6- 100% NPK + S	60.52	61.17	60.85	91.45	94.37	92.91	107.60	112.13	109.87
T_7- 100% NPK +Zn + S	65.57	67.53	66.55	101.19	106.20	103.70	123.10	133.11	128.11
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	69.79	74.37	72.08	110.86	111.96	111.41	133.25	135.68	134.46
T_9- 100% NPK + Liming @LR	60.78	63.11	61.95	95.31	98.90	97.10	117.78	124.01	120.90
T_{10}- 50% NPK + Azospirillum	54.91	56.68	55.79	87.47	89.63	88.55	99.17	104.22	101.70
T_{11}- 50% NPK + 50% N-FYM	60.77	61.61	61.19	93.83	98.30	96.07	108.03	120.31	114.17
T_{12}- 50% NPK + 50% N- VC	58.83	59.97	59.40	90.62	97.27	93.95	104.23	107.62	105.93
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	65.47	68.54	67.00	100.87	103.90	102.38	120.47	132.54	126.51
T_{14}- FYM @ 10 t ha^{-1}	55.01	57.69	56.35	90.75	92.53	91.64	103.90	104.64	104.27
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	57.37	59.41	58.39	92.20	96.35	94.28	107.97	113.26	110.62
SEm±	0.80	0.78	0.56	1.41	1.50	1.03	1.64	2.29	1.41
CD(p=0.05)	2.32	2.26	1.59	4.10	4.34	2.92	4.74	6.65	3.99

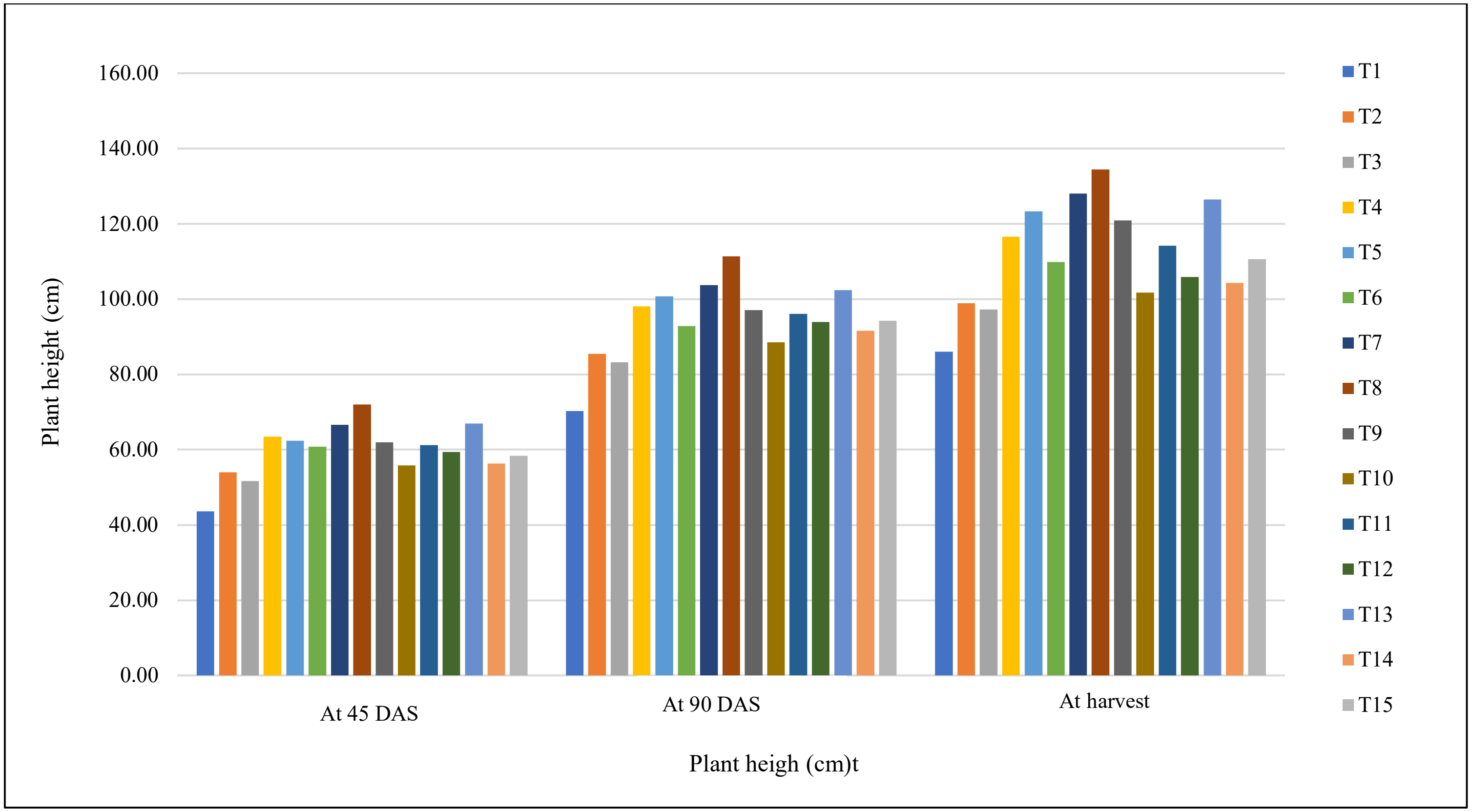


Fig 4.1: Effect of soil fertility management on plant height in direct seeded rice

better root penetration leading to better absorption of moisture and nutrients thus better plant height and growth.

4.1.2 Number of tillers plant^{-1}

The data for the number of tillers plant^{-1} at 45 and 90 DAS are presented clearly in table 4.2 and graphically portrayed in fig 4.2.

The number of tillers plant^{-1} from the table showed that the highest number of tillers were recorded with the application of inorganic fertilizers in combination with organic sources *i.e.,* T_8 at both stages of the plant growth. The data also showed that during the initial growth stages of the plant the number of tillers recorded more while in the later stages, the increase in number of tillers gradually declined during both years of the experiment. The highest number of tillers plant^{-1} *i.e.,* 5.40 and 5.7313 at 45 DAS, 7.47 and 7.80 at 90 DAS, respectively in the year 2021 and 2022 were recorded with treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) while the lowest were recorded with control plot T_1 with values 3.13, 3.47 at 45 DAS and 4.27, 4.87 at 90 DAS, respectively for both the years 2021 and 2022.

Increase in the number of tillers plant^{-1} at both stages of plant growth could be attributed to the fact that as sufficient nutrient was applied in the treatments it resulted in ample nutrients in the soil available pool which was ultimately taken up by the plant and increased the production of more tillers from the shoot nodes which in progression as primary, secondary and tertiary tillers. Khan *et al*. (2007) also reported that application of chemical fertilizers NPK, Zn @ 10 kg ha^{-1} (soil application) along with inorganic sources like green manure or FYM gave significantly higher number of tillers and other yield attributes as compared to NPK alone and the control. Mondal *et al*. (2020) and Ghasal *et al*. (2015) also gave similar conclusion where they reported the number of tillers in rice increased with application of NPK and zinc together.

Tillering is the product of expanding auxiliary buds and is closely associated with nutritional condition of mother culm during its early growth

Table 4.2: Effect of soil fertility management on number of tillers in direct seeded rice

Treatments	Number of tillers plant^{-1}					
	45 DAS			90 DAS		
	2021	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	3.13	3.47	3.30	4.27	4.87	4.57
T_2- 100% NPK	3.93	4.27	4.10	5.53	6.13	5.83
T_3- 50% NPK	3.87	4.07	3.97	5.47	5.80	5.63
T_4- SSNM (109:30:46 NPK)	4.67	4.83	4.75	6.83	7.07	6.95
T_5- 100% NPK + Zn	4.73	4.93	4.83	7.00	7.20	7.10
T_6- 100% NPK + S	4.33	4.53	4.43	6.27	6.73	6.50
T_7- 100% NPK +Zn + S	4.80	5.00	4.90	7.03	7.40	7.22
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	5.40	5.73	5.57	7.47	7.80	7.63
T_9- 100% NPK + Liming @LR	4.67	4.87	4.77	6.93	7.20	7.07
T_{10}- 50% NPK + Azospirillum	4.07	4.53	4.30	5.63	6.20	5.92
T_{11}- 50% NPK + 50% N-FYM	4.60	4.80	4.70	6.73	6.90	6.82
T_{12}- 50% NPK + 50% N- VC	4.33	4.67	4.50	6.20	6.67	6.43
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	4.73	5.13	4.93	7.00	7.20	7.10
T_{14}- FYM @ 10 t ha^{-1}	4.27	4.53	4.40	6.80	7.00	6.90
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	4.40	4.80	4.60	6.47	6.80	6.63
SEm±	0.17	0.15	0.11	0.15	0.13	0.10
CD(p=0.05)	0.50	0.42	0.32	0.43	0.37	0.28

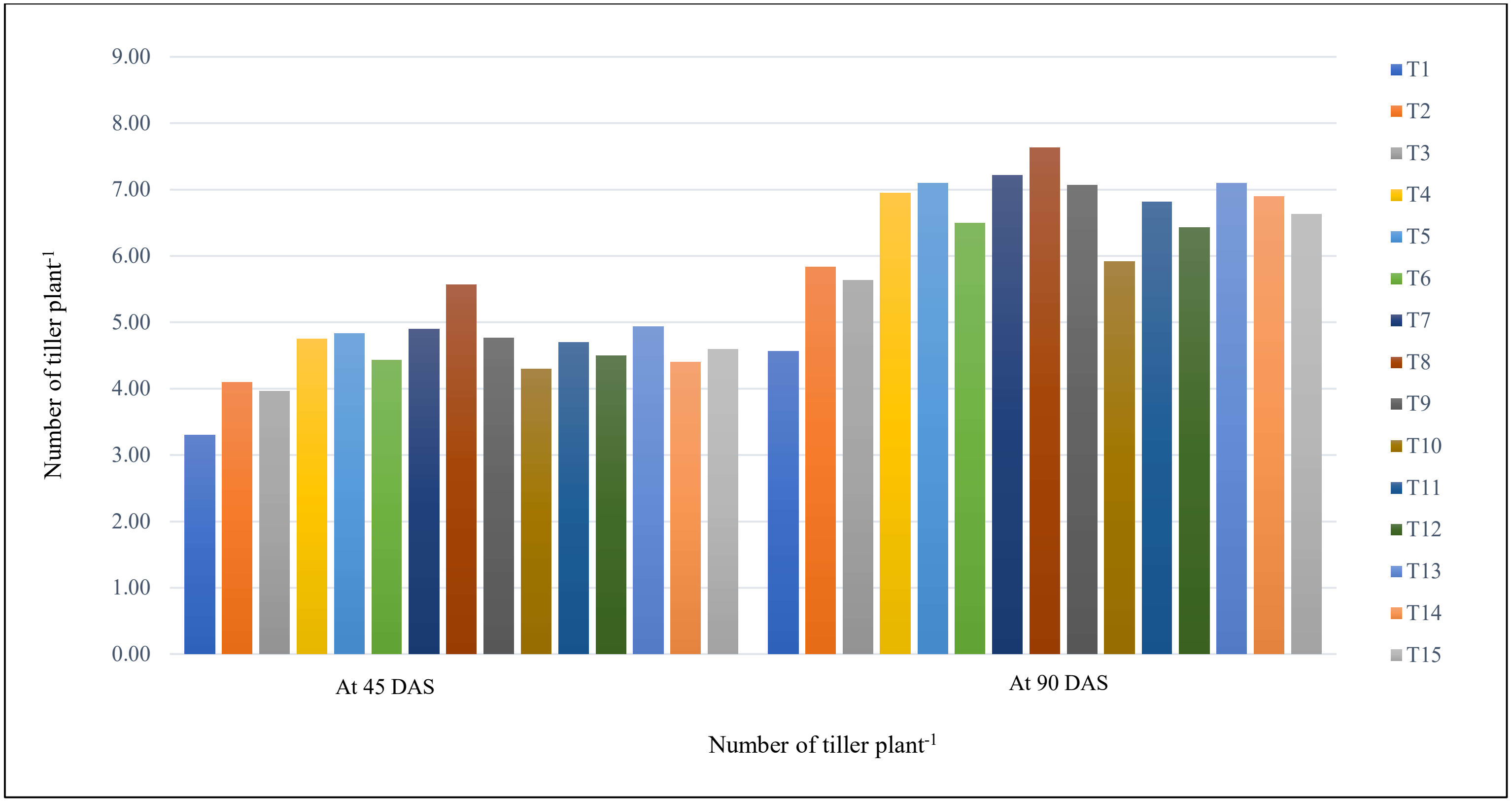


Fig 4.2: Effect of soil fertility management on number of tiller plant^{-1} in direct seeded rice

period which gets improved by the application of sulphur as it improves use efficiency of other nutrient particularly nitrogen and phosphorus (Ram *et al*., 2014). S and Zn play an important role in various physiological and metabolic processes which contribute to increase plant productivity which include N-metabolism, protein biosynthesis, gene expression, pollination, and tolerance to biotic and abiotic stress (Cakmak *et al*. 2023, Hawkesford *et al*. 2023). They also further confirmed that combined application of S with Zn improved the plant growth and yield attributes due to their synergistic interactions between the Zn and S at cellular levels. Zenda *et al*. (2021) and Narayan *et al*. (2022) have also reported the positive effect of S fertilization on crop productivity depends on various factors like varieties, interaction with nutrients, and soil condition such as soil organic matter and zinc availability. The finding of this study is in line with Khampuang *et al*. (2023) where he confirmed that application of moderate Zn and adequate S increased the number of tillers per plant by 13.4% and 29.2 %, respectively compared with low S rates. Decomposition of FYM in soil also produces organic acids which acts a chelating agent for zinc in the soil thus proving its availability to the plants. Mirza *et al*. (2005) also reported that productive tillers hill^{-1} were increased by the application of FYM along with different macro and micronutrients.

4.1.3 Crop growth rate (g m^{-2} day^{-1})

Results of different treatments on crop growth rate at 45 and 90 DAS have been presented in the table 4.3 and graphically elucidated in fig 4.3. As indicated in the data table, application of 100% NPK + Zn + S + FYM @ 5t ha^{-1} significantly affected the crop growth rate at both stages of plant growth. It was evident from the table that the highest CGR for 0-45 DAS was recorded from T_8 with 3.70 and 4.02 g m^{-2} day^{-1} for the year 2021 and 2022, respectively and a pooled data of 3.86 g m^{-2} day^{-1}. Similarly, at 45-90 DAS T_8 also recorded highest with 7.07 and 7.06 g m^{-2} day^{-1} for both the years 2021 and 2022 with a pooled data of 7.07 g m^{-2} day^{-1}, respectively. The lowest crop growth rate at 0-45 DAS was observed in control treatment T_1 with 2.18 and 2.29 g m^{-2} day^{-1} for 2021 and 2022 and pooled data 2.24 g m^{-2} day^{-1}, similarly at 45-90 DAS T_1 recorded 5.05 and 5.14 g m^{-2} day^{-1} for 2021 and 2022 with pooled data of 5.09 g m^{-2} $day^{-1,}$ respectively. It was also observed from the data that in the year 2021, T_8 at 0-45 DAS was at par with T_7 while for the year 2022 T_8 recorded significantly highest among all the treatments at both stages of crop growth.

The availability of all the nutrients in available forms in sufficient amount through adequate nutrient supply, encourages the uptake of nutrients by the plant roots thus improving the overall crop growth at different stages of growth. Inorganic fertilizers coupled with organic sources like FYM significantly improved the uptake of nutrients at its peak time. As during the initial growth of the plant, inorganic sources of nutrients helped in providing the nutrients while at latter stage the decomposed organic sources due to its slow decomposition rate steadily released the nutrients required for the plant. Enhanced performance with T_8 in respect to crop growth rate could be explained by greater released and supply of nutrients in varied proportions and times from the combined used of organic manure FYM and chemical fertilizer along with application of Zinc and Sulphur as basal doses. This result on the effect of different proportions of chemical fertilizers and organic sources on influencing growth attributes of rice were also reported by Ganguly *et al*. (2019), Rama *et al*. (2020) and Behera *et al*. (2021).

4.1.4 Relative growth rate (g $g^{-1}$$day^{-1}$)

The data pertaining to relative growth rate influenced by the different treatments under study are presented in table 4.3 and figuratively displayed in fig 4.4.

It has been observed that treatments with a higher and balanced dose of essential macro and micronutrients proved to have more beneficial effect on the crop relative growth rate. The highest were recorded with a value of 0.3 g g^{-1} day^{-1} for treatments T_5, T_7, T_8, and T_{13} respectively at 0-45 DAS for the year 2021.

Table 4.3: Effect of soil fertility management on CGR and RGR in direct seeded rice

Treatments	CGR (g m^{-2} day^{-1})						RGR (g g^{-1} day^{-1})					
	0-45 DAS			45-90 DAS			0-45 DAS			45-90 DAS		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	2.18	2.29	2.24	5.05	5.14	5.09	0.01	0.01	0.01	0.02	0.03	0.03
T_2- 100% NPK	2.64	2.69	2.67	6.41	6.44	6.43	0.02	0.02	0.02	0.03	0.05	0.04
T_3- 50% NPK	2.27	2.39	2.33	6.01	6.02	6.02	0.02	0.02	0.02	0.03	0.04	0.04
T_4- SSNM (109:30:46 NPK)	3.30	3.36	3.33	6.56	6.57	6.56	0.02	0.02	0.02	0.02	0.05	0.04
T_5- 100% NPK + Zn	3.47	3.58	3.52	6.62	6.67	6.65	0.03	0.03	0.03	0.02	0.05	0.04
T_6- 100% NPK + S	2.92	3.01	2.96	6.61	6.62	6.62	0.02	0.02	0.02	0.03	0.05	0.04
T_7- 100% NPK +Zn + S	3.62	3.83	3.73	6.84	6.89	6.87	0.03	0.03	0.03	0.02	0.05	0.04
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	3.70	4.02	3.86	7.07	7.06	7.07	0.03	0.03	0.03	0.02	0.05	0.04
T_9- 100% NPK + Liming @LR	3.40	3.53	3.47	6.63	6.71	6.67	0.02	0.03	0.03	0.02	0.05	0.04
T_{10}- 50% NPK + Azospirillum	2.74	2.86	2.80	6.37	6.27	6.32	0.02	0.02	0.02	0.03	0.05	0.04
T_{11}- 50% NPK + 50% N-FYM	3.19	3.31	3.25	6.55	6.47	6.51	0.02	0.02	0.02	0.02	0.05	0.04
T_{12}- 50% NPK + 50% N- VC	2.85	2.99	2.92	6.50	6.54	6.52	0.02	0.02	0.02	0.03	0.05	0.04
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	3.50	3.68	3.59	6.82	6.88	6.85	0.03	0.03	0.03	0.02	0.05	0.04
T_{14}- FYM @ 10 t ha^{-1}	2.81	2.97	2.89	6.48	6.51	6.49	0.02	0.02	0.02	0.03	0.05	0.04
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	3.17	3.32	3.24	6.56	6.58	6.57	0.02	0.02	0.02	0.03	0.05	0.04
SEm±	0.04	0.03	0.02	0.01	0.01	0.01	0.0001	0.0001	0.0001	0.0002	0.00002	0.0001
CD(p=0.05)	0.10	0.09	0.07	0.04	0.04	0.03	0.0003	0.0002	0.0002	0.0005	0.0001	0.0002

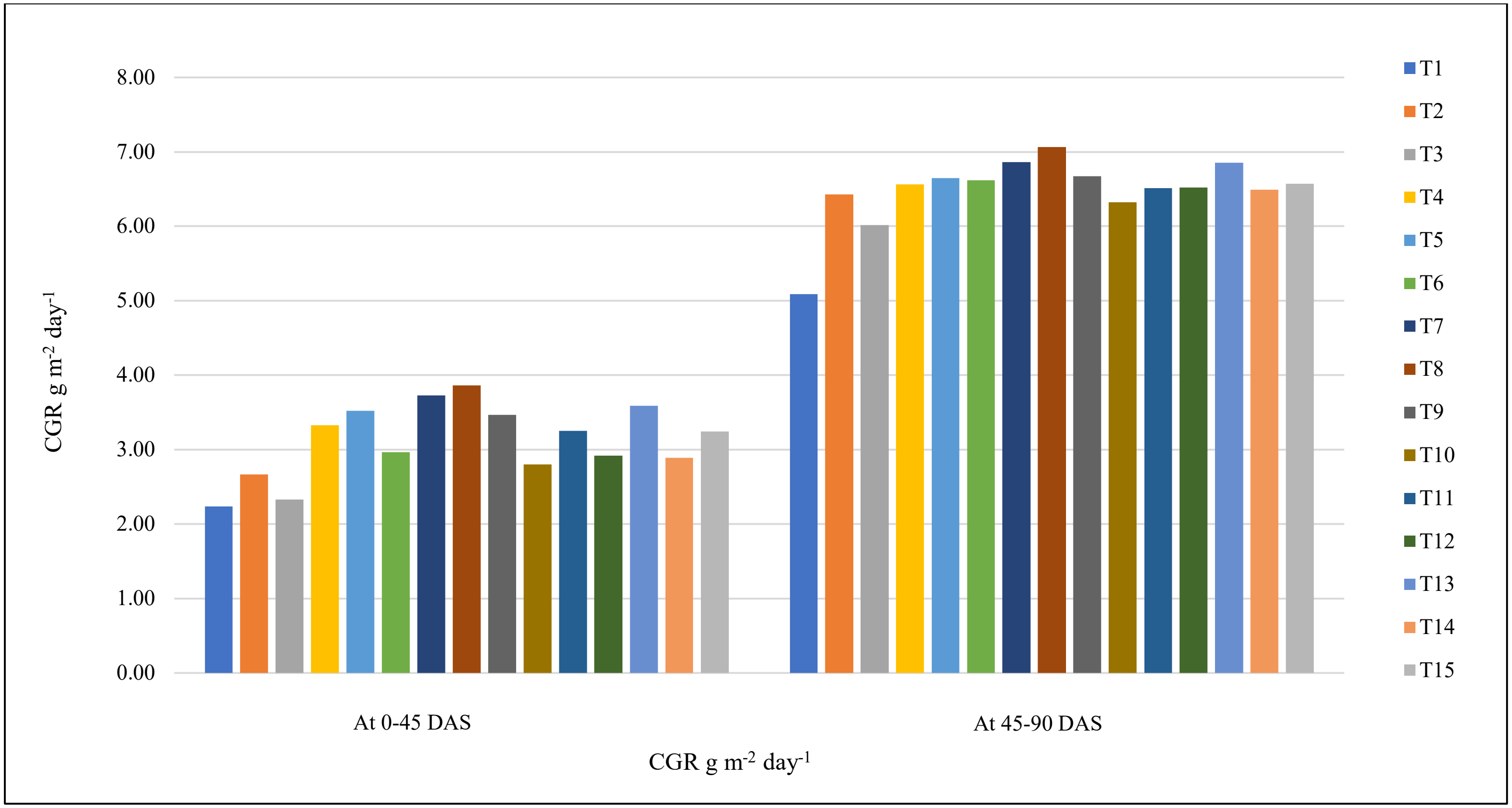


Fig 4.3 Effect of soil fertility management on CGR g m^{-2} day^{-1} in direct seeded rice

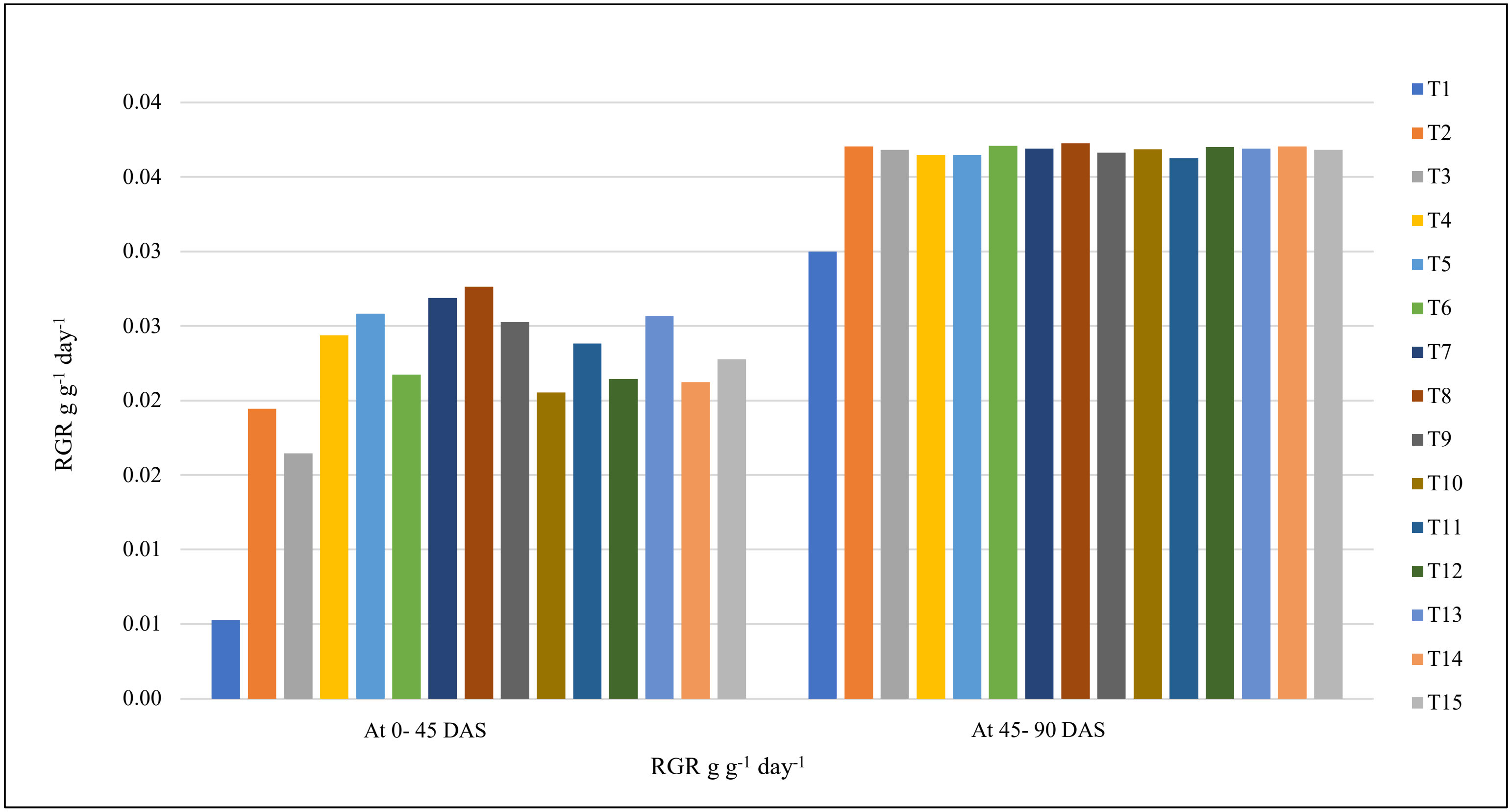


Fig 4.4: Effect of soil fertility management on RGR g $g^{-1}day^{-1}$ in direct seeded rice

Similar trends were also reported for the year 2022 with T_9 recording among the highest value for relative growth rate. The lowest was recorded with the control plot T_1 with a value of 0.1 g g^{-1} day^{-1} for both years respectively. While at 45-90 DAS, the relative growth rate was observed to have obtained the same rate of growth except in control T_1 where the pooled value varied from 0.03 to 0.04 g g^{-1} day^{-1} respectively. Similar results are also reported by Tsukru *et al*. (2023) where the dry matter accumulation like CGR and RGR were reported to have increased with a higher rate of nutrient application as compared to lower levels of nutrients where 100 kg N ha^{-1} and 40 kg P ha^{-1} performed better than other levels of N and P as well as control.

4.1.5 Length of panicle (cm)

Perusal data on length of panicle as affected by the different treatments under study in direct seeded rice has been presented in table 4.4. The findings clearly showed that treatments receiving higher levels of nutrients showed longer length of panicle in centimetre as compared to treatments that did not receive any nutrients as well as which received lesser nutrients. Among all the treatments, T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) proved to have recorded the highest length of panicle with 27.65 cm and 27.71 cm for both the years 2021 and 2022 with the pooled data of 27.68 cm, respectively. The lowest was recorded with the control T_1 with values 26.14 cm and 26.15 cm for both years 2021 and 2022 with a pooled value 26.15cm, respectively. The treatment T_8 was found to be at par with almost all the other treatments except for T_1, T_2, T_3, T_{10}, and T_{14}. This parameter was found to be non-significant statistically. However, it was evident from the results that length of panicle improved due to the increase in levels of nutrients added to the soil through both inorganic and organic sources as well. It also proved that the integrated nutrient application performed better as compared to treatments with inorganic fertilizers or organic sources alone as it encouraged the availability of nutrients throughout the growth stages of plant which further helped the plant to assimilate sufficient photosynthetic products.

Similar findings were also reported by Singh *et al*. (2018) and Mondal *et al*. (2015) who also stated that the combined use of inorganic and organic fertilizers increased the length of panicle in both the years of experimentation.

4.1.6 Number of panicle m^{-2}

The data for number of panicle m^{-2} are presented in the table 4.4 and figuratively represented in fig 4.5.

Data from the comparative study of the treatments showed that treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) performed better among all other treatments as it recorded significantly the highest number of panicles for both the years 29.67 and 31.00 respectively with the pooled data of 30.33. While the minimum number of panicles was recorded with the control treatment T_1 with 16.67 and 17.67 for the year 2021 and 2022, respectively with pooled data of 17.17. It was observed from the pooled data that application of T_8 recorded an increase of about 76.64% over control T_1, 22.94% over T_2 (100% NPK) alone. From the pooled data it was also found that statistically treatments T_4 (27.33), T_5 (29.67), T_7 (29.00) and T_{13} (28.83) were at par with treatment T_8. The following treatments are either provided with higher levels of nutrients or integrated with organic sources and therefore produced a greater number of panicle m^{-2} as compared to the other treatments. The performance of treatment T_8 proves that when nutrients were provided in ample amount with inorganic source and combining with organic sources that encourages a slow and continuous release of nutrients throughout the growth stages of the crop, enabled an assimilation of sufficient photosynthetic products which in turn increased dry matter resulting in a greater number of panicles. This finding is in conformity with Apon *et al*. (2018) who reported the highest number of panicles with treatment 100% RDF+ FYM @ 5t ha^{-1} and Naing Oo (2010) also reported the same findings. The early emergence of primary and secondary tillers at vegetative stage and supported with proper nutrient supply and translocation of food materials towards reproductive parts contributed to higher number of panicle plant^{-1} (Bajpai *et al*., 2022).

Saha *et al*. (2020) reported that combined application of $ZnSO_4$ @ 20 kg ha^{-1} along with 100% NPK + FYM @10 t ha^{-1} had produced higher number of panicle m^{-1} over 100% NPK alone. He concluded that application of $ZnSO_4$ at the studied rate along with application of FYM source and 100% NPK provided the best results under study.

4.1.7 Number of grains panicle^{-1}

The data for number of grains panicle^{-1} in direct seeded rice are documented in table 4.4 and displayed graphically in fig 4.6.

Among all the treatments under study, treatment T_8 proved to have recorded significantly the highest number of grains panicle^{-1} for both years 2021 (126.20) and 2022 (129.27) as well as in pooled data 127.73 over the control treatment T_1 with 87.93 and 91.13 for 2021 and 2022, respectively with pooled value of 89.53. Treatment T_7 recorded the second highest with the pooled value of 121.13 during the course of investigation. The control plot which did not receive any external source of nutrients proved to yield the lowest number of grains panicle^{-1} for the both the years 2021 (87.93) and 2022 (91.13) consecutively with a pooled value of 89.53.

Yadav *et al*. (2021) stated that balanced nutrients supplied through organic and inorganic fertilizers (RDF) with FYM and/or vermicompost increase the uptake of nutrients which had possibly contributed to more vegetative growth. The favourable synthesis of growth promoting constituents in plant system owing to better supply of nutrients might have resulted in higher number of grains panicle^{-1}. Similar findings were also documented by Siavoshi *et al*. (2011). More number of grains panicle^{-1} might also be due to better translocation of carbohydrates from source to sink (Shalini *et al*., 2017).

Table 4.4: Effect of soil fertility management on length of panicle, number of panicle and number of grains in direct seeded rice

Treatments	Length of panicle (cm)			Number of panicle m^{-2}			Number of grains $panicle^{-1}$		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	26.14	26.15	26.15	16.67	17.67	17.17	87.93	91.13	89.53
T_2- 100% NPK	26.20	26.24	26.22	23.00	26.33	24.67	100.60	102.67	101.63
T_3- 50% NPK	26.17	26.20	26.19	21.00	23.67	22.33	97.53	99.40	98.47
T_4- SSNM (109:30:46 NPK)	27.31	27.33	27.32	25.67	29.00	27.33	115.60	117.33	116.47
T_5- 100% NPK + Zn	27.44	27.45	27.45	26.00	29.33	27.67	116.13	116.73	116.43
T_6- 100% NPK + S	26.89	26.89	26.89	24.67	27.00	25.83	110.73	113.73	112.23
T_7- 100% NPK +Zn + S	27.60	27.62	27.61	27.33	29.67	28.50	120.47	121.80	121.13
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	27.65	27.71	27.68	29.67	31.00	30.33	126.20	129.27	127.73
T_9- 100% NPK + Liming @LR	27.41	27.46	27.43	25.67	29.00	27.33	114.00	115.27	114.63
T_{10}- 50% NPK + Azospirillum	26.42	26.35	26.38	23.00	24.33	23.67	103.07	104.33	103.70
T_{11}- 50% NPK + 50% N-FYM	27.13	27.18	27.16	25.00	27.67	26.33	112.40	112.33	112.37
T_{12}- 50% NPK + 50% N- VC	26.77	26.78	26.78	24.33	26.00	25.17	108.43	111.53	109.98
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	27.52	27.54	27.53	27.00	30.67	28.83	111.53	114.20	112.87
T_{14}- FYM @ 10 t ha^{-1}	26.34	26.34	26.34	23.33	25.67	24.50	104.47	105.67	105.07
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	26.99	26.96	26.98	26.33	27.33	26.83	110.40	112.07	111.23
SEm±	0.60	0.61	0.43	1.45	1.79	1.15	2.50	2.09	1.63
CD(p=0.05)	NS	NS	NS	4.20	5.19	3.26	7.23	6.04	4.61

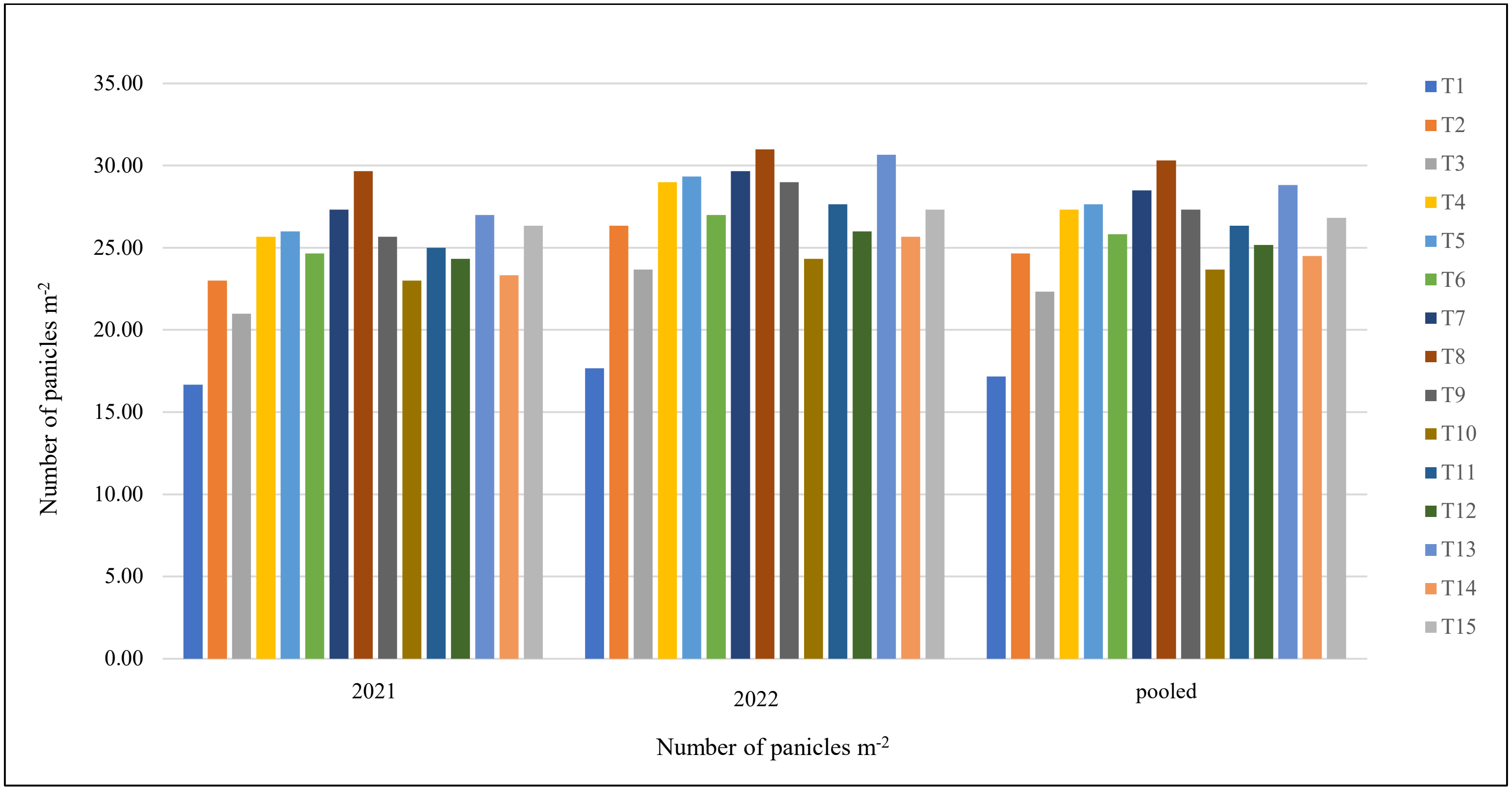


Fig 4.5: Effect of soil fertility management on number of panicles m^{-2} in direct-seeded rice

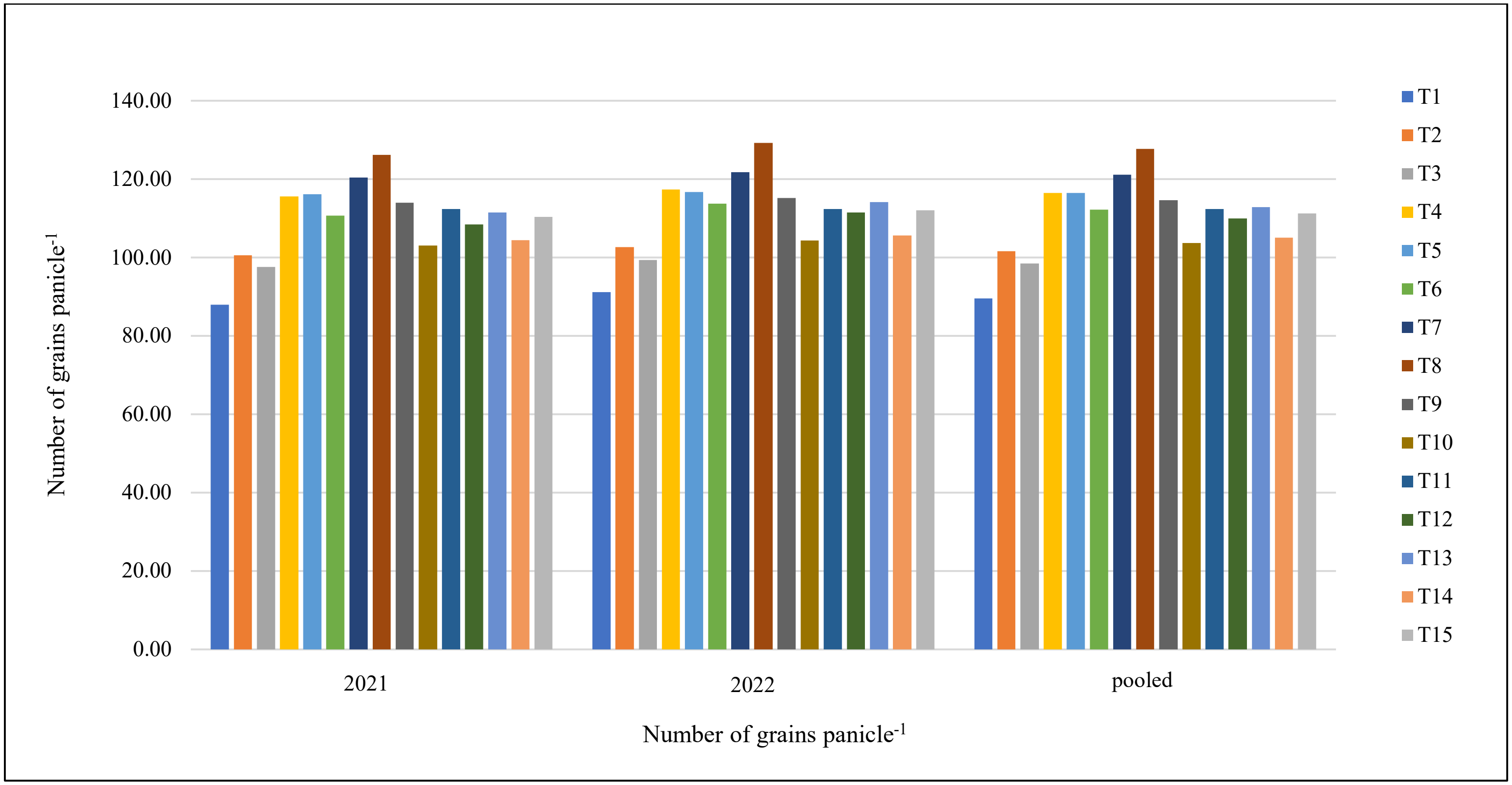


Fig 4.6: Effect of soil fertility management on number of grains panicle^{-1} in direct-seeded rice

Zinc is a precursor of tryptophan which play a crucial role in synthesis of auxins, the main factor for apical dominance, growth and further development of the plant. Sulphur plays a major role in diversion of photosynthates towards the shoot at every growth stage and marked variation was noticed at panicle initiation (PI) and maturity stages. It indicates role of sulphur is much more in signalling process of photosynthates especially after onset of reproductive stages (Rahman *et al*., 2008,). After anthesis (flowering), high concentration of Zn in plant will enhance cell differentiation while at the time of fertilization most of Zn nutrient is diverted to seed only (Singh *et al*., 2011). Due to this reason, it is evident that treatment T_8 with application of 100% NPK, Zn @ 10 kg ha^{-1}, S @ 20 kg ha^{-1} coupled with FYM proved to have the highest number of grains $panicle^{-1}$ as compared to the other treatments followed by treatment T_7 which had similar composition except with exclusion of FYM. This is in conformity with the findings of Singh *et al*. (2012) who reported that the highest number of filled grains was reported with zinc @ 6 kg ha^{-1} and S @ 40 kg ha^{-1} where S rate was also at par with S @ 20 kg ha^{-1}. As panicle initiation (PI) is onset of reproductive stage with full of green foliage and during this stage there is utmost requirement of the assimilation of photosynthates, therefore even distribution of nutrients at peak demand of crop period, continuous supply of nutrients in balanced quantity throughout the growth period of the crop is achieved through this integrated manner of nutrient supply as resulted with treatment T_8.

4.1.8 Number of filled grains $panicle^{-1}$

The data pertaining to number of filled grains $panicle^{-1}$ are presented in table 4.5 and graphically displayed in fig. 4.7.

The values in the table clearly depicts that treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) recorded the highest number of filled grains $panicle^{-1}$ for both the years 2021 and 2022 with 122.13 and 119.47, respectively, and pooled value of 120.80 while the lowest was recorded with control treatment T_1 with 79.60 and 81.67 for both the years 2021 and 2022, respectively with pooled value of 80.63. From the statistically obtained pooled value it was found that treatment T_8 had about 40.02 % more number of filled grains panicle^{-1} over control treatment T_1. This may be due to the fact that T_8 had a balance nutrient application with NPKSZn which was enhanced in the later stages due to the slow-release nature of FYM needed by the crop at the period of grain development. The second highest was also recorded with treatment T_7 with a pooled value of 115.57 and found to be statistically at par with T_8. Likewise, treatments T_4, T_5, T_9, T_{13} and T_{15} were also at par with T_8.

Grain filling in rice, or the cereals in general, is a process of systematic deposition of starch in the triploid endosperm cells forming the edible grain (Parida *et al.,* 2022). Zinc is found to be present in various dehydrogenase proteins and peptides enzymes, while it being an essential constituent of growth hormones, induces further starch formation that promotes grain filling maturation and ultimately production. Increase in growth attributes due to increased uptake of nitrogen, photosynthesis and translocation of photosynthates towards the reproductive parts might have increased the number of panicle m^{-2}, number of filled grains panicle^{-1} and other yield attributes (Imade *et al*., 2017). Adequate level of zinc in soil increases tillering and consequently increased number of panicle m^{-2} and additionally as zinc promotes pollen formation and seed production, number of grains panicle^{-1} was more in zinc applied plot than control as reported by Singh *et al*. (2018). He also reported that number of grains panicle^{-1} were significantly higher with 15 kg zinc ha^{-1} over control which were also statistically at par with zinc application of 10 kg ha^{-1}, application of sulphur @ 20 kg ha^{-1} also gave a significantly 8.58% higher as compared to control. The findings in this study are also in conformity with Singh *et al*. (2017) who reported that increasing levels of zinc and sulphur have significant response on yield attributing characters like number of filled grains panicle^{-1} where zinc level of 15 kg ha^{-1} gave the highest result which was at par with 10 kg ha^{-1} and sulphur levels of 45 kg ha^{-1} which also was at par with 30 kg ha^{-1}.

4.1.9 Number of unfilled grains panicle^{-1}

Data pertaining to number of unfilled grains panicle^{-1} are shown in table 4.5 and graphically represented in fig 4.8.

The highest number of unfilled grains panicle^{-1} was reported in control plot T_1 with 8.33 and 9.47 for the year 2021 and 2022, respectively with pooled value of 8.90, while the lowest was reported from treatment T_8 with 4.07 and 3.47 for both years 2021 and 2022, respectively with a pooled value of 3.77. It was evident from the result that with lack of nutrients it produces greater number of unfilled grains. Addition of inorganic sources of nutrients to the crop encourages continuous nutrient supply in combination with FYM with its slow-release nature enabling the plant to assimilate sufficient photosynthetic product which in turn resulted in increased panicles with more fertile grains. Similar findings are in conformity with Singh *et al*. (2015), Singh *et al*. (2020) and Neti *et al*. (2022). Noor (2017) also reported that the availability of maximum proportion N sources or other nutrient sources in the source sink interaction which is responsible for producing maximum spikelets per panicle and grain filling.

4.1.10 Test weight (g)

The size and boldness of the seed measured as 1000 grain weight as influenced by the different treatments under study are displayed in table 4.5.

The treatments under study failed to show any significant variation during both years of experimentation. However, the test weight (1000 grain weight) of rice was recorded highest with the treatment which had higher levels of NPK in conjunction with secondary and micronutrients and FYM. Treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) recorded the highest test weight among all the treatments with 25.38 g and 25.41 g for both years 2021 and 2022, respectively with a pooled value of 25.40 g while the lowest was recorded from the treatment control T_1 with 24.40 g and 24.46 g for both the years 2021 and 2022, respectively with pooled value of 24.43 g.

Table 4.5: Effect of soil fertility management on number of filled grains, number of unfilled grains and test weight in direct seeded rice

Treatments	Number of filled grains panicle^{-1}			Number of unfilled grains panicle^{-1}			Test weight (g) 1000 seeds		
	2021	2022	pooled	2021	2022	Pooled	2021	2022	pooled
T_1- Control	79.60	81.67	80.63	8.33	9.47	8.90	24.40	24.46	24.43
T_2- 100% NPK	93.80	94.40	94.10	6.67	8.27	7.47	24.73	24.79	24.76
T_3- 50% NPK	90.03	90.87	90.45	7.67	8.53	8.10	24.71	24.75	24.73
T_4- SSNM (109:30:46 NPK)	108.80	106.20	107.50	5.93	6.53	6.23	25.17	25.25	25.21
T_5- 100% NPK + Zn	110.87	111.27	111.07	4.60	5.47	5.03	24.83	24.86	24.85
T_6- 100% NPK + S	104.27	74.27	89.27	6.47	6.80	6.63	24.50	24.52	24.51
T_7- 100% NPK +Zn + S	116.27	114.87	115.57	4.20	4.33	4.27	24.37	24.83	24.60
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	122.13	119.47	120.80	4.07	3.47	3.77	25.38	25.41	25.40
T_9- 100% NPK + Liming @LR	108.07	109.20	108.63	5.93	6.07	6.00	24.57	24.67	24.62
T_{10}- 50% NPK + Azopsirillum	97.13	96.87	97.00	6.93	8.00	7.47	24.77	24.82	24.80
T_{11}- 50% NPK + 50% N-FYM	76.07	105.60	90.83	6.33	6.73	6.53	24.65	24.67	24.66
T_{12}- 50% NPK + 50% N- VC	101.83	98.20	100.02	6.60	7.07	6.83	24.59	24.63	24.61
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	113.67	111.69	112.68	4.60	5.44	5.02	24.78	24.81	24.79
T_{14}- FYM @ 10 t ha^{-1}	97.73	96.87	97.30	6.60	7.40	7.00	24.50	24.53	24.52
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	104.00	105.33	104.67	6.40	6.80	6.60	24.45	24.51	24.48
SEm±	8.52	8.01	5.84	0.36	0.30	0.24	0.31	0.31	0.22
CD(p=0.05)	24.67	23.20	16.56	1.05	0.88	0.67	NS	NS	NS

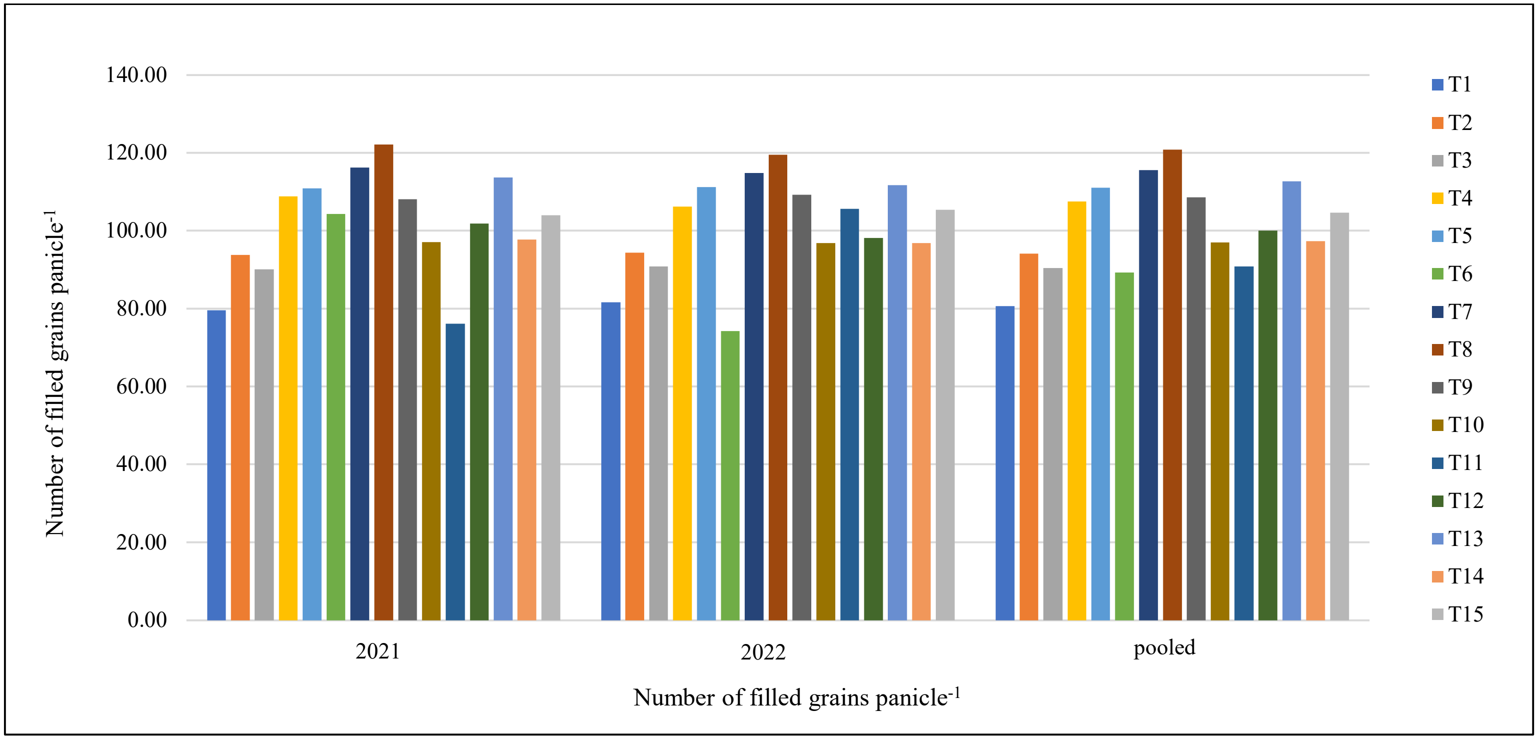


Fig 4.7: Effect of soil fertility management on number of filled grains panicle^{-1} in direct-seeded rice

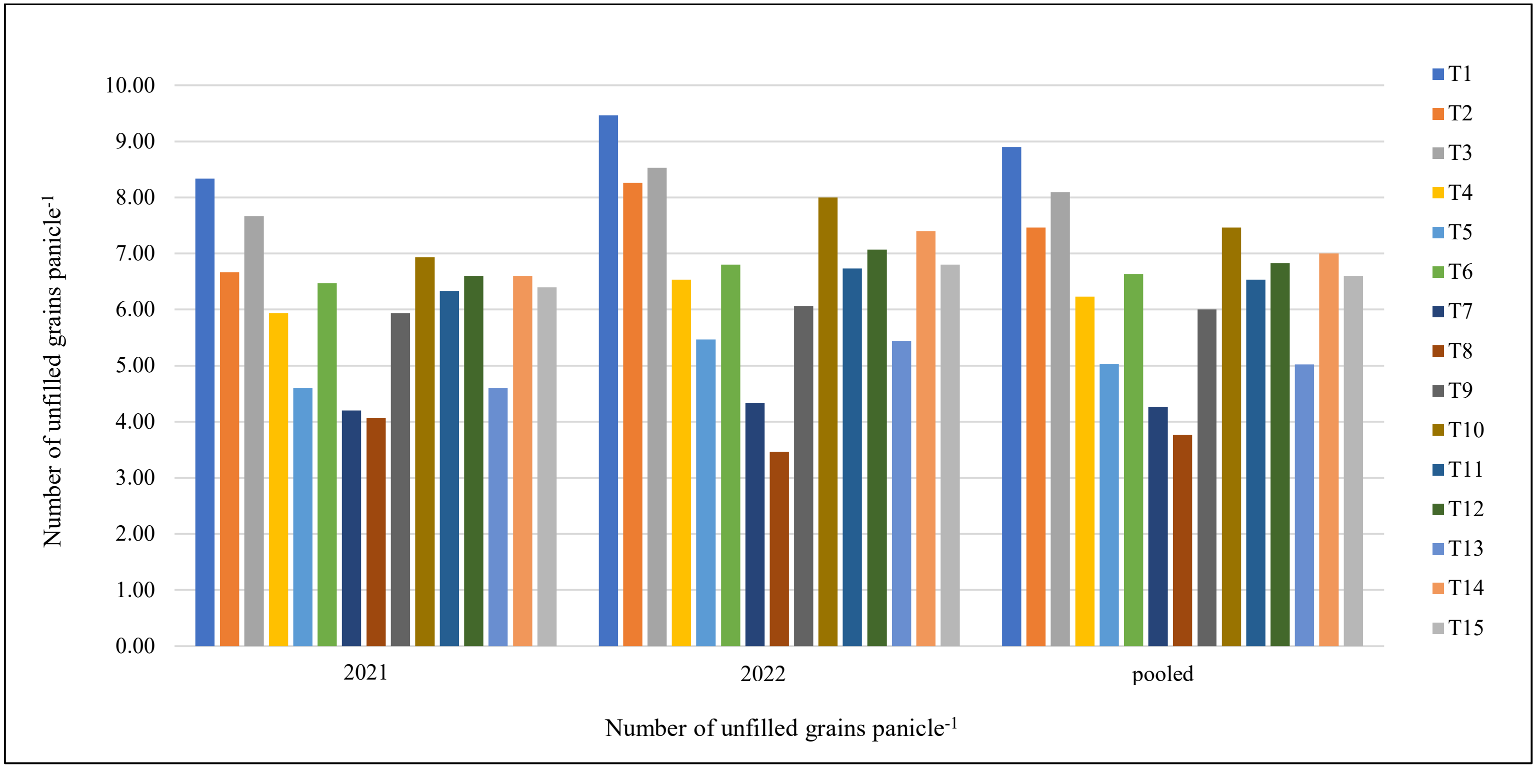


Fig 4.8: Effect of soil fertility management on number of unfilled grains panicle^{-1} in direct-seeded rice

4.1.11 Grain yield (kg ha^{-1})

Critical observation of the data recorded on grain yield (kg ha^{-1}) have been presented in the table 4.6 and depicted graphically in fig 4.9.

The highest grain yield was observed with the application of T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) which has increased grain yield to the extent of 115.46 % and 117.81 % over control during both years 2021 and 2022, respectively. The pooled value 4853.73 kg ha^{-1} recorded an increase of about 116.79 % over the control plot. It was followed by treatment T_7 (100% NPK +Zn +S) with a pooled value of 4506.68 kg ha^{-1} and T_{13} (50% NPK + 25% N-FYM + 25% N-VC) with pooled value 4343.30 kg ha^{-1}. Further evaluation of the data reflected that among the treatments, T_8 had an increase of 7.70 % and 11.75 % over treatments T_7 and T_{13}, respectively. Treatment T_8 was found to be significantly higher over all the other treatments due to its balanced and integrated nutrient application which consisted of both inorganic and organic sources as compared to control where no source of nutrients was added to the soil. Treatment T_8 performed slightly better than the other treatments like T_7 and T_{13} could be attributed to the fact that additional application of FYM @ 5 t ha^{-1} could have encouraged slow and balanced nutrient release over the later period of the crop growth which are required for its growth and development of panicles and grain development eventually improving the crop grain yield. Although treatments T_{13} had application of organic sources like FYM and Vermicompost but inorganic sources NPK were only limited to 50 % NPK as compared to T_8 which had 100 % NPK and thus could be the reason why it performed slightly inferior than treatment T_8.

Increasing grain yield might be due to nitrogen application through inorganic and organic source enhancing the dry matter production, crop growth rate, promoting elongation of internodes and activity of growth hormones like gibberellins. These results are in conformity with Singh *et al*. (2000). Several findings from Das *et al*. (2014), Bharose *et al*. (2017) and Singh *et al*. (2018) are of the opinion that instead of inorganic sources alone integrated nutrient management combination improves physiochemical and biological properties of soil which improves the efficiency in utilization of native as well as applied nutrients at faster rate, ultimately favouring plant growth and enhancing the yield components of rice. FYM being a store house of both macro and micro nutrients which might have enhanced the metabolic process vis-à-vis enlarged source and sink capacity, which ultimately enhanced the grain and straw yields (Singh *et al*., 2018). Participation of Zn in biosynthesis of indole acetic acid (IAA) and its role in initiation of primordial reproductive parts and partitioning of photosynthates towards them are responsible for increased yield (Takaki and Kushizaki, 1970). The favourable influence of applied Zn on yield may be due to its catalytic or stimulatory effect on most of the physiological and metabolic process of plants (Mandal *et al*., 2009). The zinc nutritional status of the plants plays a significant role in the impact of S fertilization on plant growth (Khampuang *et al*., 2023). Higher grain yield due to S may be attributed to the increase growth and yield character of rice and to the stimulating effect of applied S in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency, which increases the yield. Singh *et al*. (2018) also reported that the combined application of 25 kg ha^{-1} S and 10 kg ha^{-1} Zn to rice cultivation results in significant increase in grain yield, straw dry weight and harvest index.

4.1.12 Straw yield (kg ha^{-1})

The data in relation to crop straw yield are displayed in table 4.6 and graphically portrayed in fig 4.10.

From the data obtained it was evident that combination treatment of inorganic fertilizers with FYM particularly treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) recorded the highest straw yield for both the years 2021 (6121.33 kg ha^{-1}) and 2022 (6429.33 kg ha^{-1}) consecutively. Pooled data also revealed that treatment T_8 performing significantly better over all the treatments with 6275.3 kg ha^{-1}. The lowest was recorded in the control treatment T_1 for both the years 2021 and 2022 with 4263.33 and 4396.67 kg ha^{-1} and pooled value with 4330.00 kg ha^{-1}, respectively. Treatment T_8 recorded about 43.58% and 46.23% increase of straw yield over control T_1 for 2021 and 2022, and pooled value about 44.92% over control. With treatment T_8 recording significantly the highest, this was followed by treatments T_7 with 5902.00 and 6041.33 kg ha^{-1} for 2021 and 2022 with pooled value of 5971.67 kg ha^{-1} and T_{13} with 5944.00 and 5944.00 for 2021 and 2022 and with pooled value 5849.50 kg ha^{-1}, respectively. With further evaluation it was found that treatment T_{13} was found to be at par with T_5 for the year 2021 and also at par with treatment T_5 and T_9 for the year 2022. Comparison of the pooled values among the treatments showed that treatment T_8 recorded an increase of about 5.08% over T_7 and 7.27% over T_{13}, respectively. The increment in yield with treatment T_8 over other treatments can be due to the beneficial effects of organic manures on straw and grain yield probably due to additional supply of plant nutrients as well as improvement in physical and chemical properties of soil. These are in concordance with the findings of Nath *et al*. (2015) and Kumar *et al*. (2018) where they reported that integrated nutrient management proved more superior than alone application of chemical fertilizer or biofertilizers and manures. Superiority of treatment T_8 in terms of yield over other treatments can be attributed to the application of 100% RDF of inorganic fertilizer over 50% RDF which increased the availability of nutrients and emphasized on the essentiality of applying the required amount of nutrients needed for the growth and development of the plant throughout their growth stages which later was supplemented with the presence of organic sources like FYM because of its slow release and continuous availability of nutrients. This is in conformity with the findings of Singh *et al*. (2018) and Kumar *et al*. (2017). The higher yield can also be attributed to the integrated manner of nutrient combination as the final yield of both grain and straw yield is dependent upon the development of the yield components like effective tillers, panicle length, test weight, number of grains panicle^{-1} and filled grains panicle^{-1}. As all the yield attributes were recorded higher with treatment T_8 due to its combined effect of both inorganic and organic sources and eventually increased both the grain and straw yield of the crop. The lower yield with the other treatments may be attributed to either due to the absence of FYM and micronutrients. This result corroborates with the findings of Shankar *et al*. (2020) and Behera *et al*. (2021).

4.1.13 Harvest Index (%)

Perusal of data on harvest index as influenced by the different nutrient management in this study are presented in table 4.6 and displayed graphically in fig 4.11.

Harvest Index is a relationship between economic yield and biological yield. As clearly evident from the results obtained, treatment T_8 recorded the highest harvest index among all the other treatments for both the years 2021 (43.78%) and 2022 (43.36%) and pooled value of 43. 57%. While the lowest was recorded in control treatment T_1 with 31.96% and 33.98% for the year 2021 and 2022 with the pooled value 32.97%, respectively. This was followed by treatment T_5 (42.76, 43.23%) and T_{13} (42.32, 43.84%) where after further evaluation it was found that treatment T_5 was at par with T_8 for the year 2021 and both T_5 and T_{13} at par with T_8 in the year 2022. Significant increase in harvest index suggested that the plant maintained a higher supply of photosynthates to reproductive parts as compared to the vegetative biomass (Singh *et al*., 2018).

Table 4.6: Effect of soil fertility management on grain yield, straw yield and harvest index in direct seeded rice

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index (%)		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	2212.87	2264.80	2238.83	4263.33	4396.67	4330.00	31.96	33.98	32.97
T_2- 100% NPK	3287.23	3308.27	3297.75	4868.33	5134.33	5001.33	39.81	39.17	39.49
T_3- 50% NPK	3030.80	3120.93	3075.87	4706.67	5016.67	4861.67	39.13	38.34	38.74
T_4- SSNM (109:30:46 NPK)	3758.40	3859.50	3808.95	5486.67	5716.67	5601.67	40.65	40.30	40.47
T_5- 100% NPK + Zn	4045.03	4149.00	4097.02	5728.33	5925.00	5826.67	41.38	41.18	41.28
T_6- 100% NPK + S	3573.00	3668.97	3620.98	5233.67	5472.67	5353.17	40.56	40.13	40.35
T_7- 100% NPK +Zn + S	4410.70	4602.67	4506.68	5902.00	6041.33	5971.67	42.76	43.23	43.00
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	4767.87	4939.60	4853.73	6121.33	6429.33	6275.33	43.78	43.36	43.57
T_9- 100% NPK + Liming @LR	3902.83	4018.00	3960.42	5440.67	5806.33	5623.50	41.76	40.89	41.32
T_{10}- 50% NPK + Azospirillum	3229.33	3363.67	3296.50	4925.33	5606.67	5266.00	39.60	37.49	38.55
T_{11}- 50% NPK + 50% N-FYM	3677.67	3823.97	3750.82	5311.67	5682.00	5496.83	40.90	40.03	40.47
T_{12}- 50% NPK + 50% N- VC	3446.80	3612.83	3529.82	5196.67	5356.67	5276.67	39.87	40.27	40.07
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	4229.93	4456.67	4343.30	5755.00	5944.00	5849.50	42.32	42.84	42.58
T_{14}- FYM @ 10 t ha^{-1}	3442.63	3535.40	3489.02	4938.67	5250.00	5094.33	41.07	40.24	40.66
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	3254.07	3413.07	3333.57	4759.67	4898.67	4829.17	40.60	41.06	40.83
SEm±	63.37	53.74	41.55	38.14	54.14	33.11	0.37	0.33	0.25
CD(p=0.05)	183.58	155.69	117.70	110.48	156.83	93.80	1.07	0.96	0.70

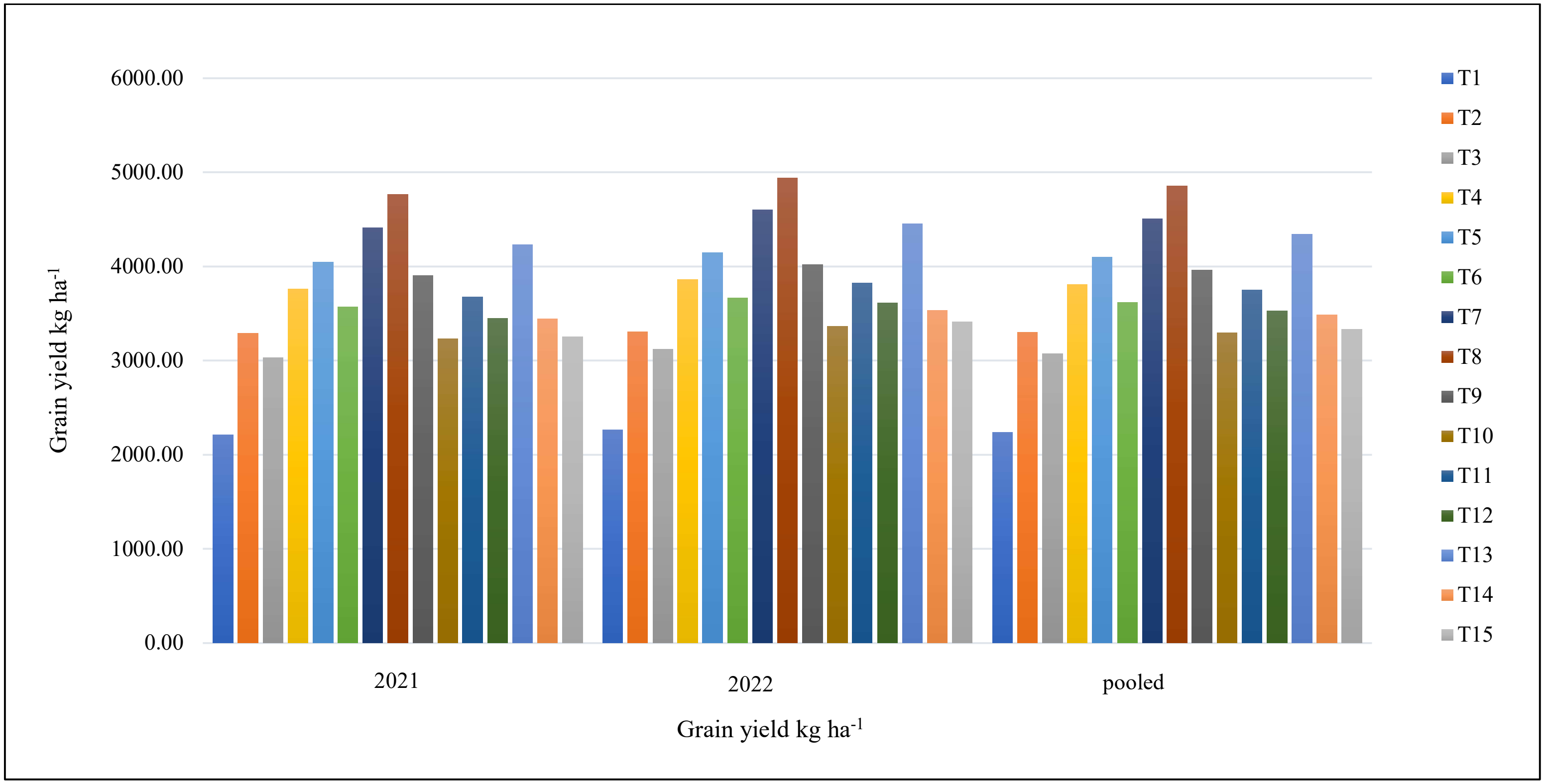


Fig 4.9: Effect of soil fertility management on grain yield kg ha^{-1} in direct-seeded rice

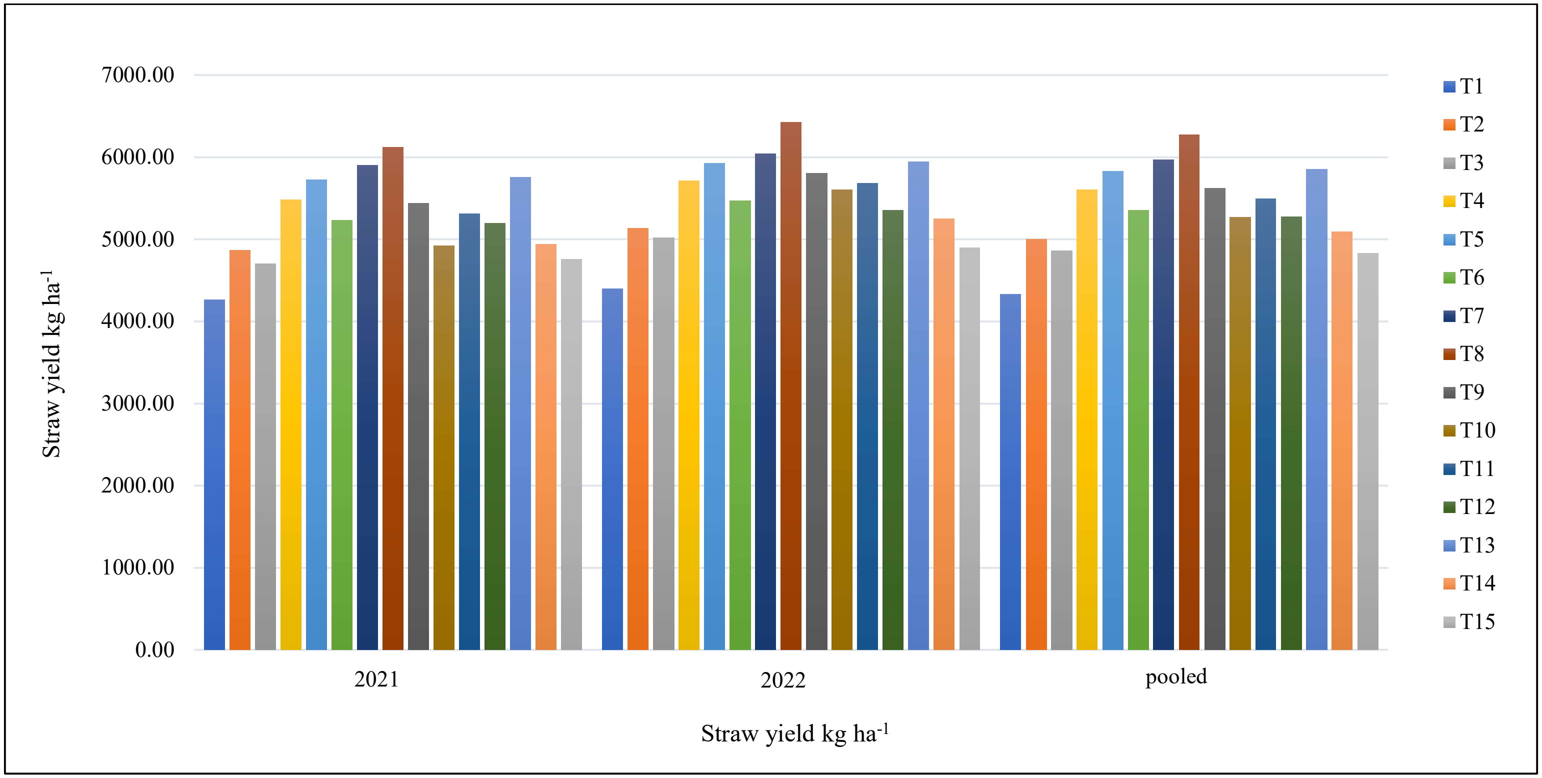


Fig 4.10: Effect of soil fertility management on straw yield kg ha^{-1} in under direct-seeded rice

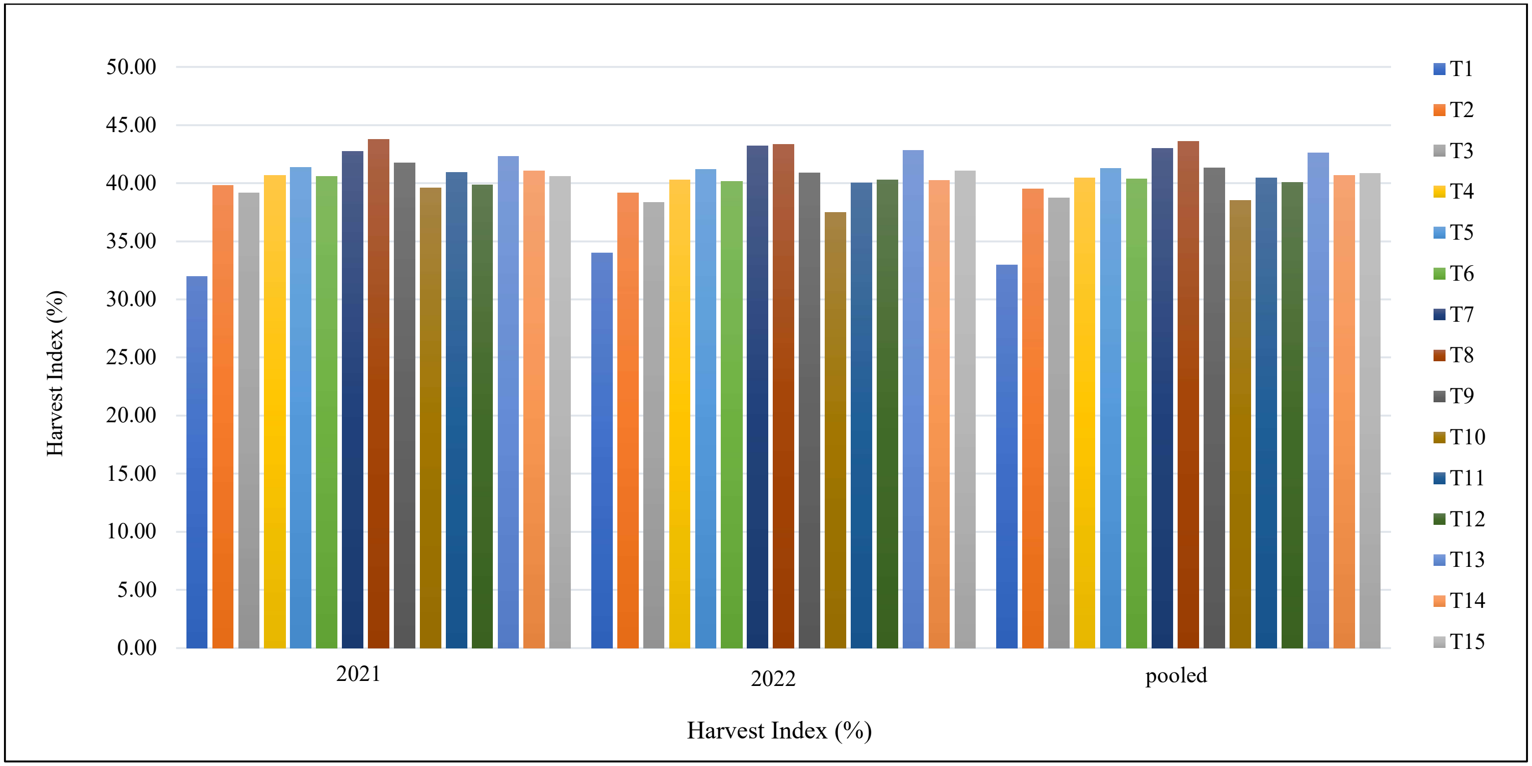


Fig 4.11: Effect of soil fertility management on harvest index (%) in direct-seeded rice

4.2 Effect of soil fertility management on nutrient content and uptake (grain and straw) in direct seeded rice.

The crop nutrient content and uptake are an essential indicator of the amount of nutrient that the crop is efficiently able to take up during the period of the crop growth and development. A detailed observation was carried out with respect to the different nutrients and recorded on how efficiently the plant was able to take up which ultimately contributed to the crop growth and yield.

4.2.1 N content in grain and straw (%)

The data pertaining to nitrogen content in grain and straw as influenced by the different treatments under the study of soil fertility management are presented in table 4.7.

Nitrogen content in grain ranged from 0.92 % to 1.19 % in 2021 and 0.93 % to 1.20 % in 2022, where treatment T_8 recorded the highest among all the treatments and T_1 recorded the lowest respectively. Pooled value also showed that T_8 obtained the highest content (1.19%) and lowest with T_1 (0.93%). Further evaluation shows that T_8 increased to an extend of 29.24% and 29.03% over the control in the year 2021 and 2022, respectively. Application of T_8 significantly increased the nitrogen content both in grain and straw for both the years which may probably be due to the combined application of inorganic fertilizers and organic manures together. This may also be due to the sufficient addition of nutrients i.e., 100% NPK with adequate doses of zinc and sulphur fertilizers to the soils in available form as compared to other treatments which had 50% NPK or no nutrients application. Additional integration of FYM could have been another reason which increased the content as FYM encourages slow release of nutrients which may have provided the plant need in the later stages of the crop. The beneficial effect of FYM might be due to its favourable effect on the availability of macro and micronutrients and better uptake of nutrients by rice grain and straw as compared to 100% NPK alone (Agarwal, 2008). The above results are in conformity with Kumar *et al*. (2008) who reported that application of 100% NPK along with FYM significantly produced higher grain yield of rice than 100% alone which might be due to better content of nitrogen, phosphorus and potassium in grain. Similar results are reported by Bora *et al*. (2018).

Similarly, the nitrogen content in straw was also observed to be significantly increased with the application of treatment T_8 with 0.51% for 2021 and 0.52% for 2022 respectively. Pooled data also recorded highest with treatment T_8 with 0.52%. Lowest straw nitrogen content in both the years 2021 and 2022 were also recorded in control T_1 with 0.43%, 0.44% and pooled value of 0.43% respectively as compared to sole application of inorganic fertilizers or organic manures alone. The higher amount of N in grain as compared to straw might be attributed to the translocation of the N occurring from vegetative part to the reproductive organ or senescence of leaves (Islam *et al*., 2016). Integration of inorganic fertilizers and organic manures along with other macro and micronutrients proved to have more significant effect on plant straw nitrogen content in this study. A study from Paul *et al*. (2013) also reported that continuous and balanced supply of N, P, K, and Zn along with FYM led to better nutrient content in grain and straw which further enhanced the crop yield. This is also in conformity with Bora *et al*. (2018).

4.2.2 P content in grain and straw (%)

The data relating to phosphorus content in grain and straw influenced by the different treatments in this study are displayed in table 4.7.

The data showed that treatment T_8 with the highest level of NPK nutrients, secondary nutrients and micronutrients through inorganic fertilizers along with FYM significantly increased the phosphorus content in grain with 0.29% and 0.31% during both years 2021 and 2022 while pooled value with 0.30% respectively whereas the lowest phosphorus content in grain were recorded with the control treatment T_1 which had no nutrient application in both years 2021 and 2022 with 0.15%, 0.18% and pooled value of 0.16%. From the pooled data it was observed that P content in grain was found to increase by

87.5% over control with application of treatment T_8. Similarly, phosphorus content in straw was found highest in T_8 with 0.90% and 0.90% for 2021 and 2022 with pooled value of 0.90%, respectively. The lowest phosphorus content in straw was observed in control treatment T_1 with 0.06%, 0.07% for 2021 and 2022 and pooled value of 0.07%, respectively. In the year 2022, phosphorus content in straw with treatment T_8 was recorded at par with treatment T_7 while remaining significantly highest over all the other treatments. Further evaluation of pooled data indicated that P content in straw with T_8 increased to an extent of 28.57% over control T_1.

From the results obtained it was evident that application of nutrients increased the phosphorus content in grain and straw except for control, therefore the increased in phosphorus content in grain and straw could be due to the application of adequate available nutrients from the inorganic as well as the organic sources. Addition of FYM led to a more significant increase in the content for both grain and straw. Application of secondary nutrients like sulphur and calcium apart from NPK and micronutrients like zinc also proved to have enhanced the nutrient content as compared to other treatments. Similar findings on increased concentration of P in grain and straw due to increased nutrient level and integration with organic sources have also been reported by Bora *et al*. (2018) and Latha *et al*. (2019). The optimum and continuous availability of nutrient to plant gave increase nutrient uptake as well as assimilation in plant tissues leading to improved nutrient content in the crop. Dash *et al*, (2015) and Mousomi *et al*. (2020) also reported that combined application of all the nutrients increased nutrient accumulation and uptake and reduction of N, P, K or N and P from the fertilizer package decreased the content as well as the NPK uptake in crop.

Table 4.7: Effect of soil fertility management on N and P content in grain and straw in direct seeded rice

Treatments	N content (%)						P content (%)					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	0.92	0.93	0.93	0.43	0.44	0.43	0.15	0.18	0.16	0.06	0.07	0.07
T_2- 100% NPK	1.06	1.08	1.07	0.44	0.45	0.44	0.22	0.24	0.23	0.07	0.07	0.07
T_3- 50% NPK	0.97	1.02	0.99	0.44	0.44	0.44	0.21	0.23	0.22	0.07	0.07	0.07
T_4- SSNM (109:30:46 NPK)	1.14	1.15	1.14	0.47	0.48	0.48	0.24	0.26	0.25	0.08	0.08	0.08
T_5- 100% NPK + Zn	1.15	1.16	1.16	0.49	0.50	0.49	0.25	0.26	0.26	0.08	0.08	0.08
T_6- 100% NPK + S	1.16	1.16	1.16	0.45	0.47	0.46	0.22	0.25	0.23	0.08	0.08	0.08
T_7- 100% NPK +Zn + S	1.18	1.17	1.17	0.51	0.52	0.52	0.27	0.29	0.28	0.08	0.09	0.08
T_8- 100% NPK +Zn +S + FYM @5t ha^{-1}	1.19	1.20	1.19	0.51	0.52	0.51	0.29	0.31	0.30	0.09	0.09	0.09
T_9- 100% NPK + Liming @LR	1.15	1.16	1.16	0.48	0.49	0.49	0.25	0.27	0.26	0.08	0.08	0.08
T_{10}- 50% NPK + Azospirillum	1.08	1.09	1.09	0.44	0.45	0.45	0.21	0.23	0.22	0.07	0.07	0.07
T_{11}- 50% NPK + 50% N-FYM	1.13	1.14	1.13	0.47	0.48	0.47	0.24	0.25	0.25	0.08	0.08	0.08
T_{12}- 50% NPK + 50% N- VC	1.12	1.14	1.13	0.45	0.47	0.46	0.22	0.24	0.23	0.08	0.08	0.08
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	1.16	1.17	1.16	0.49	0.50	0.50	0.26	0.28	0.27	0.08	0.08	0.08
T_{14}- FYM @ 10 t ha^{-1}	1.12	1.13	1.12	0.44	0.45	0.45	0.21	0.24	0.23	0.07	0.07	0.07
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	1.13	1.14	1.13	0.46	0.47	0.47	0.23	0.25	0.24	0.08	0.08	0.08
SEm±	0.02	0.02	0.01	0.01	0.01	0.004	0.01	0.01	0.005	0.001	0.0004	0.0004
CD(p=0.05)	0.05	0.05	0.04	0.02	0.02	0.01	0.02	0.02	0.01	0.002	0.001	0.001

4.2.3 K content in grain and straw (%)

The data regarding the potassium content in grain and straw of rice are presented in table 4.8.

A critical examination of all the data showed that potassium content in grain and straw of rice crop was significantly influenced by all the treatments (T_2 to T_{15}) except for the control treatment (T_1). It was observed that application of T_8 i.e., 100% NPK + S + Zn +F YM @ 5t ha^{-1} proved to have the highest content of potassium in both grain and straw and significantly highest compared to other treatments. In grain content, T_8 recorded higher for the both the years 2021 (0.44%) and 2022 (0.45%) with pooled value of 0.41% while the lowest was in T_1 with 0.30% for 2021, 0.31% for 2022 and pooled value of 0.30%, respectively. From the pooled data it was observed that application of T_8 potassium content in grain increased by 36.66% over control. Further evaluation revealed that T_5 (0.42%), T_7 (0.42%) and T_{13} (0.42%) were at par with T_8.

From the data recorded it became apparent that maximum potassium content in straw was recorded with treatment T_8 with 1.32% and 1.33% for 2021 and 2022 with pooled value of 1.33%, respectively while the minimum was recorded with control T_1 with 1.03%, 1.05% for 2021 and 2022 with pooled value of 1.04%, respectively.

Accumulation of K in straw was found to be higher than grain. The increased K content in both grain and straw with application of T_8 over all other treatments was indicative of the fact that omission of any nutrient element from the treatment led to decline in efficient uptake and accumulation of nutrients by the plants as a result of the absence of any nutrient element. Dash *et al*. (2015) also reported that deletion of Zn, B and S from the schedule along with NPK significantly decreased the accumulation of K nutrient in the plant. Application of zinc and sulphur also proved to have enhanced the K content in both grain and straw along with NPK and FYM. Similar finding was also reported by Singh *et al*. (2012) where addition of zinc level 6 kg ha^{-1} and sulphur level 20 kg ha^{-1}

significantly increased the K content in rice and documented that combination of sulphur and zinc had significant effect on concentration and uptake as they play important role in growth and development.

4.2.4 S content in grain and straw (%)

The data pertaining to sulphur content in grain and straw of rice are presented in table 4.8.

It was apparent from the data that integrated application of inorganic fertilizers and organic source of nutrients proved to record higher sulphur content in grain and straw of rice crop. Also, it has been observed that the plots particularly fertilized with sulphur source of fertilizers showed higher sulphur content in both the grain and straw as compared to other treatments which did not have sulphur application. Maximum sulphur content in grain was reported with the application of treatment T_7 and T_8 both with 0.47% for the year 2021 and was found to be at par with T_5 that recorded 0.45% in the same year, respectively. In 2022, treatment T_8 recorded highest with 0.49% and on critical evaluation reported at par with T_7 which recorded 0.48% while lowest was recorded in control T_1 with 0.25%, 0.26% for both 2021 and 2022 while the pooled value of 0.26, respectively. Further evaluation showed that T_7 was at par with T_5 and T_6 both with a sulphur content of 0.46% respectively. Pooled data revealed that sulphur treated plots recorded a higher S content than other treatments from which T_7 and T_8 recorded the highest with a value of 0.48%. Meanwhile the straw content of sulphur was also recorded highest in treatment T_8 for both the years 2021 (0.23%) and 2022 (0.24%) with pooled value 0.24% respectively while the lowest was recorded in control T_1 with 0.16%, 0.17% for both the years 2021 and 2022 while 0.16% as pooled value. Further evaluation from the pooled data reported that treatment T_8 was statistically at par with T_6, T_7, T_9, T_{11}, and T_{12}, respectively.

It was evident that plots which were treated with sulphur comparatively recorded more sulphur content both in grain and straw than the other treatments

Table 4.8: Effect of soil fertility management on K and S content in grain and straw in direct seeded rice

Treatments	K content (%)						S content (%)					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	Pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	0.30	0.31	0.30	1.03	1.05	1.04	0.25	0.26	0.26	0.16	0.17	0.16
T_2- 100% NPK	0.34	0.36	0.35	1.10	1.13	1.12	0.26	0.27	0.27	0.20	0.20	0.20
T_3- 50% NPK	0.33	0.34	0.34	1.10	1.10	1.10	0.36	0.37	0.37	0.19	0.19	0.19
T_4- SSNM (109:30:46 NPK)	0.40	0.41	0.40	1.24	1.27	1.25	0.44	0.45	0.45	0.19	0.20	0.20
T_5- 100% NPK + Zn	0.42	0.43	0.42	1.27	1.30	1.28	0.45	0.46	0.46	0.21	0.20	0.20
T_6- 100% NPK + S	0.39	0.40	0.39	1.19	1.21	1.20	0.44	0.46	0.45	0.21	0.22	0.22
T_7- 100% NPK +Zn + S	0.42	0.43	0.42	1.30	1.31	1.31	0.47	0.48	0.48	0.22	0.23	0.23
T_8- 100% NPK +Zn +S + FYM @5t ha^{-1}	0.44	0.45	0.44	1.32	1.33	1.33	0.47	0.49	0.48	0.23	0.24	0.24
T_9- 100% NPK + Liming @LR	0.41	0.42	0.41	1.25	1.28	1.27	0.37	0.39	0.38	0.22	0.23	0.23
T_{10}- 50% NPK + Azospirillum	0.35	0.36	0.36	1.13	1.15	1.14	0.44	0.45	0.45	0.20	0.20	0.20
T_{11}- 50% NPK + 50% N-FYM	0.39	0.40	0.39	1.22	1.24	1.23	0.38	0.40	0.39	0.21	0.22	0.22
T_{12}- 50% NPK + 50% N- VC	0.36	0.37	0.37	1.17	1.19	1.18	0.38	0.39	0.39	0.21	0.22	0.22
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	0.41	0.43	0.42	1.29	1.31	1.30	0.39	0.41	0.40	0.19	0.19	0.19
T_{14}- FYM @ 10 t ha^{-1}	0.36	0.38	0.37	1.14	1.16	1.15	0.36	0.35	0.36	0.18	0.20	0.19
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	0.37	0.39	0.38	1.20	1.23	1.22	0.36	0.35	0.35	0.19	0.20	0.19
SEm±	0.01	0.01	0.01	0.001	0.001	0.001	0.01	0.01	0.01	0.01	0.01	0.01
CD(p=0.05)	0.03	0.03	0.02	0.004	0.003	0.003	0.02	0.02	0.01	0.03	0.03	0.02

but even among the sulphur treated plots integration with FYM proved to have had a superlative effect on the sulphur content of the crop. This result is in conformity with Islam *et al*. (2013) who advocated that integration of inorganic fertilizers along with FYM gave more sulphur concentration in the rice crop as compared to other treatments which had inorganic fertilizers or organic manures alone. Kumar *et al*. (2017) also studied the need for inclusion of sulphur and zinc along with recommended dose of NPK in rice for its growth and development. He reported that sulphur content of rice both grain and straw increased with the increasing rates of sulphur up to 60 kg ha^{-1} while zinc also proves the same trend with zinc @ 6 kg ha^{-1} performing the best among all the levels. The amount of NPKS and Zn absorbed by grain and straw of rice crop is directly correlated with yield and the contents of these nutrients in grain and straw. Similar findings were also reported by Islam *et al*. (2016) that sulphur content in grain and straw was improved with sulphur rates up to 200% of recommended dose of sulphur fertilizer which was about 20 kg ha^{-1} along NPKZn.

4.2.5 Ca content in grain and straw (%)

The results on calcium content in grain and straw of rice crop are presented in table 4.9. It was apparent from the data that maximum calcium content in grain for both the years 2021 and 2022 was 0.09, 0.08% and pooled value of 0.09% recorded with treatment T_8 with combined application of 100% NPK + Zn + S+ FYM @ 5 t ha^{-1}, whereas the minimum calcium content in grain was recorded in control treatment T_1 with 0.05 and 0.06%. A critical examination of the data revealed that pooled calcium content in grain increased from 0.06% to 0.09%. Application of treatment T_8 improved the calcium content in grain to the extent of 50 % over control T_1. The results are in accordance with findings of Shormy *et al*. (2013) who reported that concentration of Ca increased with the addition of farm yard manure. However, the calcium content in grain data did not show any statistical differences during both years of experimentation thus observed to be non-significant. Whereas the highest calcium content in straw, was recorded with the lime treated plot T_9 and T_{13} both with 1.05% and lowest observed in control T_1 with 0.96% for the year 2021. While the year 2022, it was recorded highest with T_4, T_7, T_8, T_9, T_{13}, and T_{15} with 1.06% while the lowest was found in control T_1 with 0.99%, respectively. Pooled value shows that calcium content increased from 0.98% to 1.05%. However, the calcium content in straw was also found to be non-significant. Leaching of the nutrient due to the dislocation of calcium from the sites of exchange to the soil solution leading to the decline in calcium (Alexandre *et al*., 2019) might also have been a factor for the less content in plant and the non-significant effects of the treatments in both grain and straw.

4.2.6 Zn content in grain and straw (%)

Data pertaining to zinc content in grain and straw are presented in table 4.9. A careful examination of the data recorded showed that plots that had plots that had zinc fertilization gave higher zinc content in both grain and straw during both years of experimentation. In grain, the highest was recorded in treatment T_8 (100% NPK + Zn + S+ FYM @ 5 t ha^{-1}) for both years 2021 with 30.37% and 2022 with 30.46% and pooled value of 30.42%, while the minimum was recorded in control T_1 with 27.50% and 27.61% for 2021 and 2022 and pooled value of 27.56% respectively. Careful evaluation from the pooled data among the zinc treated plots shows that treatment T_8 was followed by T_7 (30.39%) and T_5 (29.66%). However, the zinc content in grain was found to be non-significant during both years of experimentation. Similarly in straw content, the highest zinc content was recorded with treatment T_8 (44.42% and 44.53%) and lowest with control T_1 (39.82% and 39.90%) for both years of experimentation 2021 and 2022 respectively. Pooled data showed that the values for zinc content varied from 39.86% to 44.48%. Similarly, even for the zinc content in straw, zinc treated plots showed higher values as compared to other treatments. Zinc content in straw was also found to be non-significant among all the treatments. Careful observation with the data recorded showed that even among the zinc treated plots

Table 4.9: Effect of soil fertility management on Ca and Zn content in grain and straw in direct seeded rice

Treatments	Ca content (%)						Zn content (mg kg^{-1})					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	0.05	0.06	0.06	0.96	0.99	0.98	27.50	27.61	27.56	39.82	39.90	39.86
T_2- 100% NPK	0.06	0.07	0.07	1.02	1.05	1.03	28.18	28.33	28.25	42.03	42.06	42.05
T_3- 50% NPK	0.06	0.07	0.06	1.01	1.04	1.03	28.09	28.11	28.10	41.71	41.73	41.72
T_4- SSNM (109:30:46 NPK)	0.07	0.07	0.07	1.02	1.06	1.04	29.15	29.17	29.16	43.92	43.93	43.92
T_5- 100% NPK + Zn	0.07	0.08	0.08	1.03	1.05	1.04	29.61	29.72	29.66	44.35	44.39	44.37
T_6- 100% NPK + S	0.06	0.07	0.07	1.02	1.05	1.04	29.59	29.64	29.62	44.27	44.31	44.29
T_7- 100% NPK +Zn + S	0.08	0.08	0.08	1.04	1.06	1.05	30.34	30.44	30.39	44.37	44.45	44.41
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	0.09	0.08	0.09	1.04	1.06	1.05	30.37	30.46	30.42	44.42	44.53	44.48
T_9- 100% NPK + Liming @LR	0.08	0.07	0.08	1.05	1.06	1.05	29.60	29.64	29.62	43.64	43.66	43.65
T_{10}- 50% NPK + Azospirillum	0.07	0.07	0.07	1.04	1.05	1.04	28.46	28.55	28.51	40.73	40.75	40.74
T_{11}- 50% NPK + 50% N-FYM	0.08	0.07	0.07	1.03	1.05	1.04	29.03	29.11	29.07	43.37	43.39	43.38
T_{12}- 50% NPK + 50% N- VC	0.07	0.08	0.07	1.04	1.04	1.04	28.40	28.45	28.43	42.90	42.92	42.91
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	0.08	0.08	0.08	1.05	1.06	1.06	28.63	28.64	28.63	43.46	43.51	43.48
T_{14}- FYM @ 10 t ha^{-1}	0.06	0.07	0.07	1.03	1.05	1.04	28.56	28.62	28.59	41.53	41.57	41.55
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	0.07	0.06	0.07	1.04	1.06	1.05	28.75	28.79	28.77	41.52	41.57	41.54
SEm±	0.01	0.01	0.01	0.02	0.02	0.02	0.83	0.88	0.61	1.68	1.52	1.13
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

treatment T_8 recorded slightly higher than the other zinc treated plots, which gives the possibility that maybe the application of FYM might have influenced the better availability of zinc ions in soil due to the chelating nature of organic manures, which form complexes with the metal ions and thus enhancing the uptake of the available nutrient by the plant roots. However statistically both the content in grain and straw did not show any statistical difference among the treatments under study.

4.2.7 Fe content in grain and straw (%)

Data pertaining to iron content in grain and straw are presented in table 4.10. As evident from the data, iron content in grain and straw during both the years of experimentation was found to be non-significant. On examining the recorded data, it was found that treatment T_8 recorded the highest iron content in grain among all the other treatments with 58.57% and 58.61% while the lowest was recorded in control T_1 with 57.23% and 57.39% for both years of experimentation respectively. Pooled data of iron content in grain varied from 57.31% to 58.59%. Similarly, for iron content in straw the highest was recorded with treatment T_8 with 97.32% and 97.33% and lowest with control T_1 with 93.04% and 93.13% for 2021 and 2022 respectively. Pooled data for iron content in straw varied from 93.08% to 97.33%. However, the various treatments could not reach the level of significance for iron content in straw.

4.2.8 Mn content in grain and straw (%)

The data with regard to manganese content in grain and straw are shown in table 4.10. As clearly depicted from the data, manganese content in grain and straw during both the years of experimentation was found to be non-significant. On examining the recorded data, it was found that treatment T_8 recorded the highest manganese content in grain among all the other treatments with 49.88% and 49.96% while the lowest was recorded with control T_1 with values 42.14% and 42.25% for both years of experimentation respectively. Pooled data for manganese content in grain varied from 42.40% to 49.92%. Similarly, for

Table 4.10: Effect of soil fertility management on Fe and Mn content in grain and straw in direct seeded rice

Treatments	Fe content (mg kg^{-1})						Mn content (mg kg^{-1})					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	57.23	57.39	57.31	93.04	93.13	93.08	42.14	42.25	42.20	63.20	63.39	63.30
T_2- 100% NPK	57.59	57.62	57.61	94.81	94.83	94.82	43.49	43.62	43.56	63.88	63.92	63.90
T_3- 50% NPK	57.26	57.69	57.48	94.46	94.48	94.47	43.11	43.27	43.19	62.70	63.83	63.27
T_4- SSNM (109:30:46 NPK)	57.79	57.81	57.80	96.46	96.48	96.47	46.48	46.55	46.52	65.66	65.70	65.68
T_5- 100% NPK + Zn	55.90	55.91	55.91	96.80	96.78	96.79	46.99	47.04	47.02	66.18	66.21	66.19
T_6- 100% NPK + S	58.27	58.31	58.29	96.07	96.11	96.09	45.35	45.46	45.41	64.91	64.88	64.90
T_7- 100% NPK +Zn + S	58.24	58.28	58.26	97.20	97.25	97.23	48.56	48.63	48.59	66.75	66.78	66.76
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	58.57	58.61	58.59	97.32	97.33	97.33	49.88	49.96	49.92	66.96	66.98	66.97
T_9- 100% NPK + Liming @LR	58.44	58.46	58.45	96.76	96.79	96.78	49.06	49.12	49.09	65.86	65.75	65.80
T_{10}- 50% NPK + Azospirillum	56.47	56.51	56.49	95.42	95.47	95.45	43.72	43.76	43.74	64.20	64.28	64.24
T_{11}- 50% NPK + 50% N-FYM	56.28	56.30	56.29	96.42	96.11	96.27	47.87	47.93	47.90	65.35	65.41	65.38
T_{12}- 50% NPK + 50% N- VC	55.17	55.18	55.18	95.95	95.96	95.96	44.33	44.38	44.35	64.80	65.51	65.16
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	57.47	57.51	57.49	96.99	97.05	97.02	48.21	48.29	48.25	66.45	66.48	66.47
T_{14}- FYM @ 10 t ha^{-1}	57.90	57.96	57.93	95.84	95.90	95.87	45.53	45.58	45.56	64.41	64.49	64.45
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	57.48	57.49	57.49	96.22	96.32	96.27	46.54	46.62	46.58	65.00	65.13	65.07
SEm±	0.98	1.08	0.73	1.17	1.23	0.85	2.31	2.60	1.74	1.49	1.49	1.05
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

manganese content in straw the highest was recorded with treatment T_8 with 66.96% and 66.98% and lowest in control T_1 with 62.20% and 62.39% for 2021 and 2022 respectively. Pooled data for manganese content in straw varied from 62.30% to 66.97%. However, the various treatments could not reach the level of significance for manganese content in straw.

4.2.9 Cu content in grain and straw (%)

Perusal data on copper content in grain and straw as influenced by different treatments under study are shown in table 4.11. The copper content both in grain and straw during both the years of experimentation was found to be non-significant. Further examination of the recorded data, it was found that treatment T_8 recorded the highest copper content in grain among all the other treatments with 7.78% and 7.88% while the lowest was recorded in control T_1 with values 4.96% and 5.04% for both years of experimentation respectively. Pooled data varied from 5.00% to 7.83% copper content in grain. Likewise, copper content in straw the highest was recorded with treatment T_8 with 11.33% and 11.34% and lowest in control T_1 with 8.12% and 8.20% for 2021 and 2022 respectively. Pooled data for copper content in straw varied from 8.16% to 11.34%. However, the various treatments could not reach the level of significance for copper content in straw.

Table 4.11: Effect of soil fertility management on Cu content in grain and straw in direct seeded rice

Treatments	Cu content (mg kg^{-1})					
	Grain			Straw		
	2021	2022	pooled	2021	2022	pooled
T_1- Control	4.96	5.04	5.00	8.12	8.20	8.16
T_2- 100% NPK	5.42	5.45	5.44	8.01	8.26	8.14
T_3- 50% NPK	5.35	5.39	5.37	7.86	7.95	7.90
T_4- SSNM (109:30:46 NPK)	7.25	7.26	7.26	9.79	9.83	9.81
T_5- 100% NPK + Zn	7.09	7.13	7.11	10.27	10.20	10.24
T_6- 100% NPK + S	6.83	6.86	6.85	9.84	9.73	9.79
T_7- 100% NPK +Zn + S	7.74	7.75	7.75	11.23	11.21	11.22
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	7.78	7.88	7.83	11.33	11.34	11.34
T_9- 100% NPK + Liming @LR	7.54	7.58	7.56	10.75	10.73	10.74
T_{10}- 50% NPK + Azospirillum	5.59	5.55	5.57	8.87	8.75	8.81
T_{11}- 50% NPK + 50% N-FYM	6.84	6.88	6.86	10.24	10.34	10.29
T_{12}- 50% NPK + 50% N- VC	6.56	6.68	6.62	9.67	9.62	9.64
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	7.15	7.21	7.18	11.01	10.49	10.75
T_{14}- FYM @ 10 t ha^{-1}	6.28	6.48	6.38	9.29	9.33	9.31
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	6.53	6.67	6.60	9.90	9.84	9.87
SEm±	0.94	0.94	0.66	1.21	1.07	0.81
CD(P=0.05)	NS	NS	NS	NS	NS	NS

4.2.10 N uptake in grain and straw (kg ha^{-1})

The data pertaining to nitrogen uptake by grain and straw under the soil fertility management of direct seeded rice are summarized in table 4.12 and graphically portrayed in fig 4.12 and fig 4.13.

As evident from the results obtained, the maximum N uptake by grain and straw was recorded in T_8 - 100% NPK +Zn +S + FYM @ 5t ha^{-1} with the value of 56.66 kg ha^{-1} and 59.28 kg ha^{-1} by grain and 31.36 kg ha^{-1} and 33.22 kg ha^{-1} by straw during the year 2021 and 2022 respectively. From the pooled value maximum values by treatment T_8 was observed as compared to all the other treatments with 57.97 kg ha^{-1} in grain and 32.29 kg ha^{-1} in straw, respectively. While the minimum value was recorded in control treatment T_1 with 20.41 kg ha^{-1} and 21.14 kg ha^{-1} in grain for the year 2021 and 2022 with pooled value of 20.78 kg ha^{-1} respectively. Similarly, treatment T_8 recorded 18.35 kg ha^{-1} and 19.17 kg ha^{-1} for 2021 and 2022 with pooled value18.76 kg ha^{-1}, respectively for N uptake in straw. Further evaluation of the data revealed that as T_8 recorded significantly the highest it was followed by treatment T_7 (100% NPK +Zn + S) and T_{13} (50% NPK + 25% N-FYM + 25% N-VC) for both grain and straw during both the years 2021 and 2022. The N uptake for grain in the year 2022, it was found that T_7 (53.96 kg ha^{-1}) was at par with T_{13} (52.05 kg ha^{-1}). Critical examination of the pooled value showed that grain N uptake in plots receiving treatment T_8 was enhanced by 178.97% over control T_1 and 9.56% over treatment T_7, 14.72% over T_{13} while in straw N uptake 72.12% over control T_1, 4.76% over T_7 and 10.81% over T_{13} with the application of treatment T_8.

Higher assimilation of nutrients in plant tissue as well as biomass production attributed to increase nutrient uptake as abundance of nutrients were made available to the plants through both inorganic and organic sources. Sahu *et al*. (2020) also reported that combined application of inorganic fertilizers along with organic manures encouraged N uptake as compared to inorganic fertilizers alone. The higher N uptake may also be associated with the exploration of greater soil volume by root exacerbated by sulphur application (Mandal *et al*., 2003). The concomitant increase in root biomass allowing capturing of more N from the soil, and thus increasing N uptake by the plant and synergism between N and S ameliorate N uptake (Salvagiotti *et al*., 2009).

4.2.11 P uptake in grain and straw (kg ha^{-1})

The uptake of phosphorus in rice crop by the soil fertility management with different treatments under study were presented table 4.12 and graphically depicted in fig 4.14 and fig 4.15.

The results revealed that maximum P uptake of (13.67 kg ha^{-1} and 15.31 kg ha^{-1}) in grain during the year 2021 and 2022 for the treatment T_8, with pooled value of 14.49 kg ha^{-1}, while minimum was recorded with control value of 3.35 kg ha^{-1} and 4.02 kg ha^{-1} with pooled value of 3.69 kg ha^{-1} respectively. A critical examination of the pooled data indicated treatment T_8 was followed by T_7 (12.56 kg ha^{-1}), T_{13} (11.74 kg ha^{-1}), it also recorded an enhancement of P uptake with about 292.68% over control, 15.36% over T_7 and 23.42% over T_{13} respectively. Similarly, the P uptake in straw was also recorded maximum with treatment T_8 with value of 5.22 kg ha^{-1} and 5.53 kg ha^{-1} for both the years of field trails while the pooled value also recorded highest with 5.38 kg ha^{-1}. Further evaluation in pooled data shows that treatment T_8 phosphorus uptake in straw was enhanced by 84.24% over control T_1, 6.74% over T_7 and 10.02% over T_{13} respectively.

The phosphorus uptake both in grain and straw was influenced due to the availability of nutrients in optimum amount through inorganic and organic sources from the available nutrient pool leading to the development of root biomass and root surface area ultimately encouraging more uptake of nutrients by the plant roots. The lower concentration in both grain and straw in control plot maybe due to the mining of nutrient with continuous cropping without incorporation of nutrient over a long period of time (Sahu *et al*., 2020). Phosphorus uptake in both grain and straw was also significantly influenced due to the application of sulphur which was in conformity with Islam *et al*. (2016).

Table 4.12: Effect of soil fertility management on N and P uptake in grain and straw in direct seeded rice

Treatments	N uptake (kg ha^{-1})						P uptake (kg ha^{-1})					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	20.41	21.14	20.78	18.35	19.17	18.76	3.35	4.02	3.69	2.76	3.09	2.92
T_2- 100% NPK	34.81	35.52	35.17	21.34	23.04	22.19	7.23	7.82	7.53	3.54	3.78	3.66
T_3- 50% NPK	29.29	31.70	30.49	20.49	21.82	21.16	6.36	7.18	6.77	3.34	3.61	3.48
T_4- SSNM (109:30:46 NPK)	42.77	44.33	43.55	26.01	27.69	26.85	9.14	9.91	9.53	4.35	4.59	4.47
T_5- 100% NPK + Zn	46.68	48.00	47.34	27.85	29.35	28.60	10.24	10.77	10.51	4.68	4.92	4.80
T_6- 100% NPK + S	41.38	42.63	42.00	23.64	25.85	24.74	7.86	9.01	8.43	4.00	4.23	4.11
T_7- 100% NPK +Zn + S	51.86	53.96	52.91	30.28	31.37	30.82	11.76	13.36	12.56	4.94	5.14	5.04
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	56.66	59.28	57.97	31.36	33.22	32.29	13.67	15.31	14.49	5.22	5.53	5.38
T_9- 100% NPK + Liming @LR	44.83	46.66	45.75	26.02	28.59	27.31	9.89	10.86	10.38	4.35	4.78	4.57
T_{10}- 50% NPK + Azospirillum	34.98	36.76	35.87	21.59	25.36	23.48	6.75	7.70	7.23	3.61	4.11	3.86
T_{11}- 50% NPK + 50% N-FYM	41.46	43.61	42.54	24.86	27.35	26.10	8.70	9.68	9.19	4.14	4.53	4.33
T_{12}- 50% NPK + 50% N- VC	38.53	41.01	39.77	23.26	24.93	24.10	7.58	8.67	8.13	3.91	4.07	3.99
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	49.00	52.05	50.53	28.47	29.82	29.14	11.00	12.48	11.74	4.78	5.01	4.89
T_{14}- FYM @ 10 t ha^{-1}	38.39	40.03	39.21	21.94	23.76	22.85	7.35	8.48	7.92	3.67	3.92	3.80
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	36.73	38.85	37.79	21.91	23.09	22.50	7.59	8.53	8.06	3.68	3.84	3.76
SEm±	0.74	0.83	0.56	0.39	0.37	0.27	0.24	0.33	0.21	0.04	0.05	0.03
CD(p=0.05)	2.15	2.42	1.58	1.14	1.08	0.77	0.70	0.97	0.59	0.12	0.14	0.09

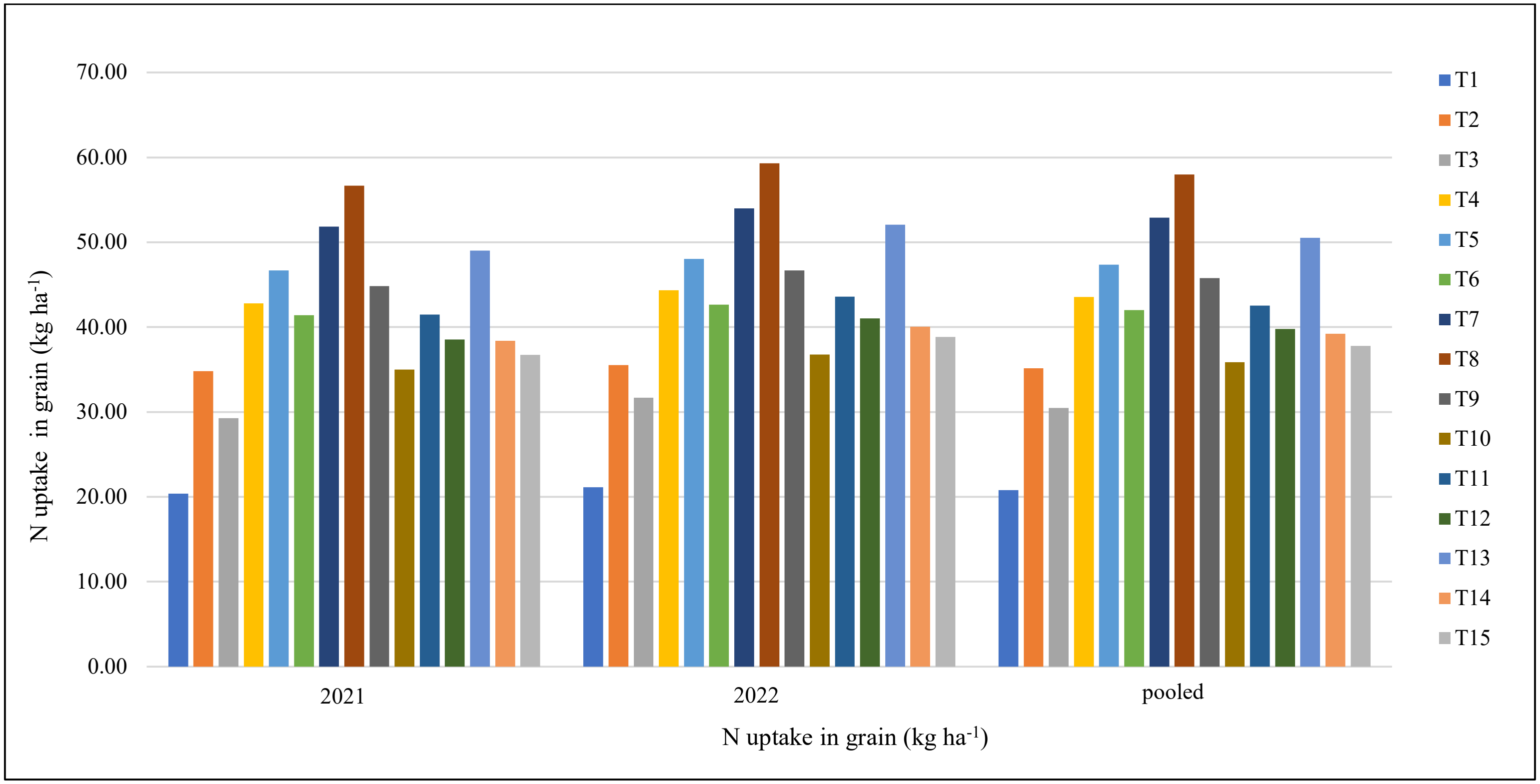


Fig 4.12: Effect of soil fertility management on N uptake in grain (kg ha^{-1}) in direct-seeded rice

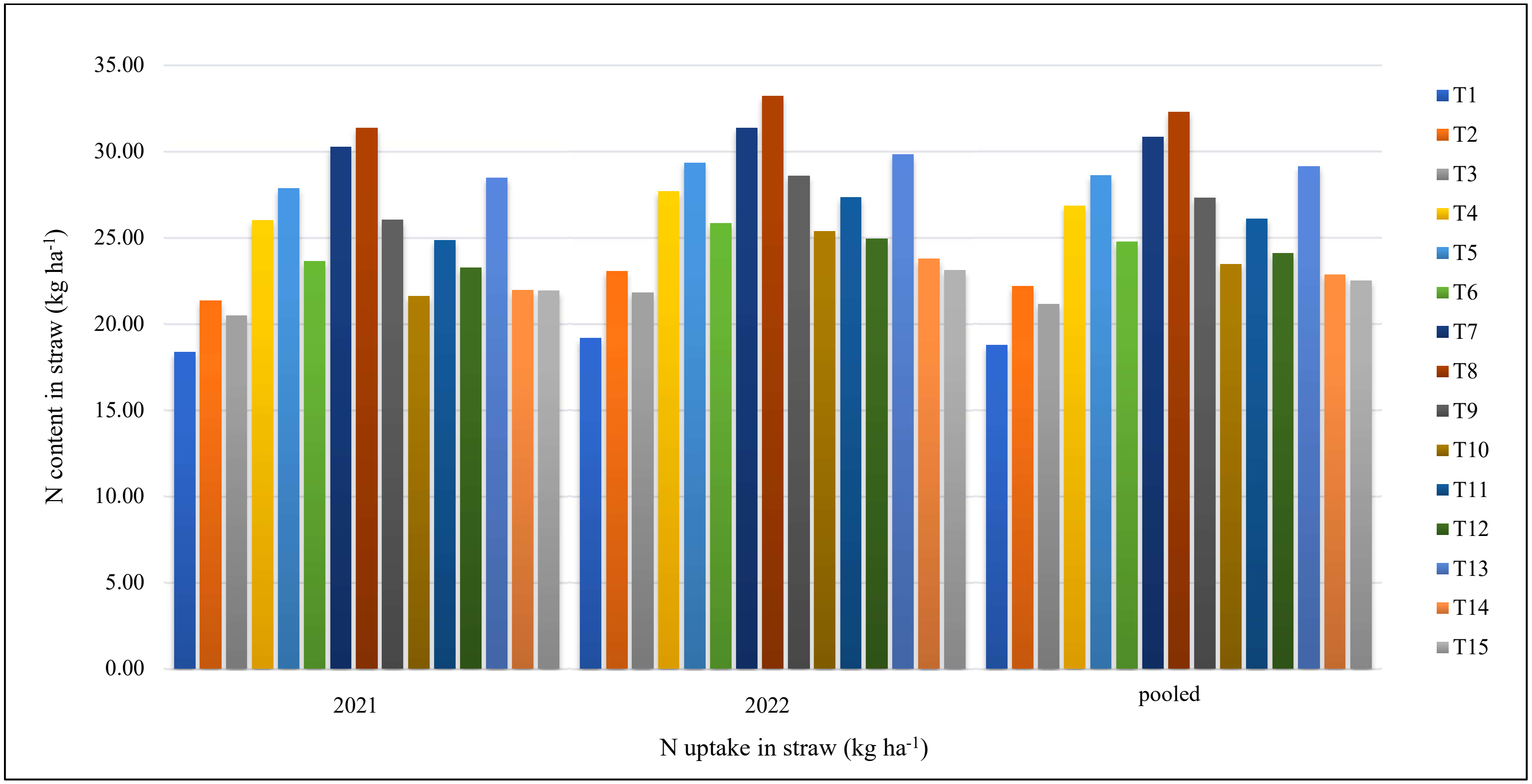


Fig 4.13: Effect of soil fertility management on N uptake in straw (kg ha^{-1}) in direct-seeded rice

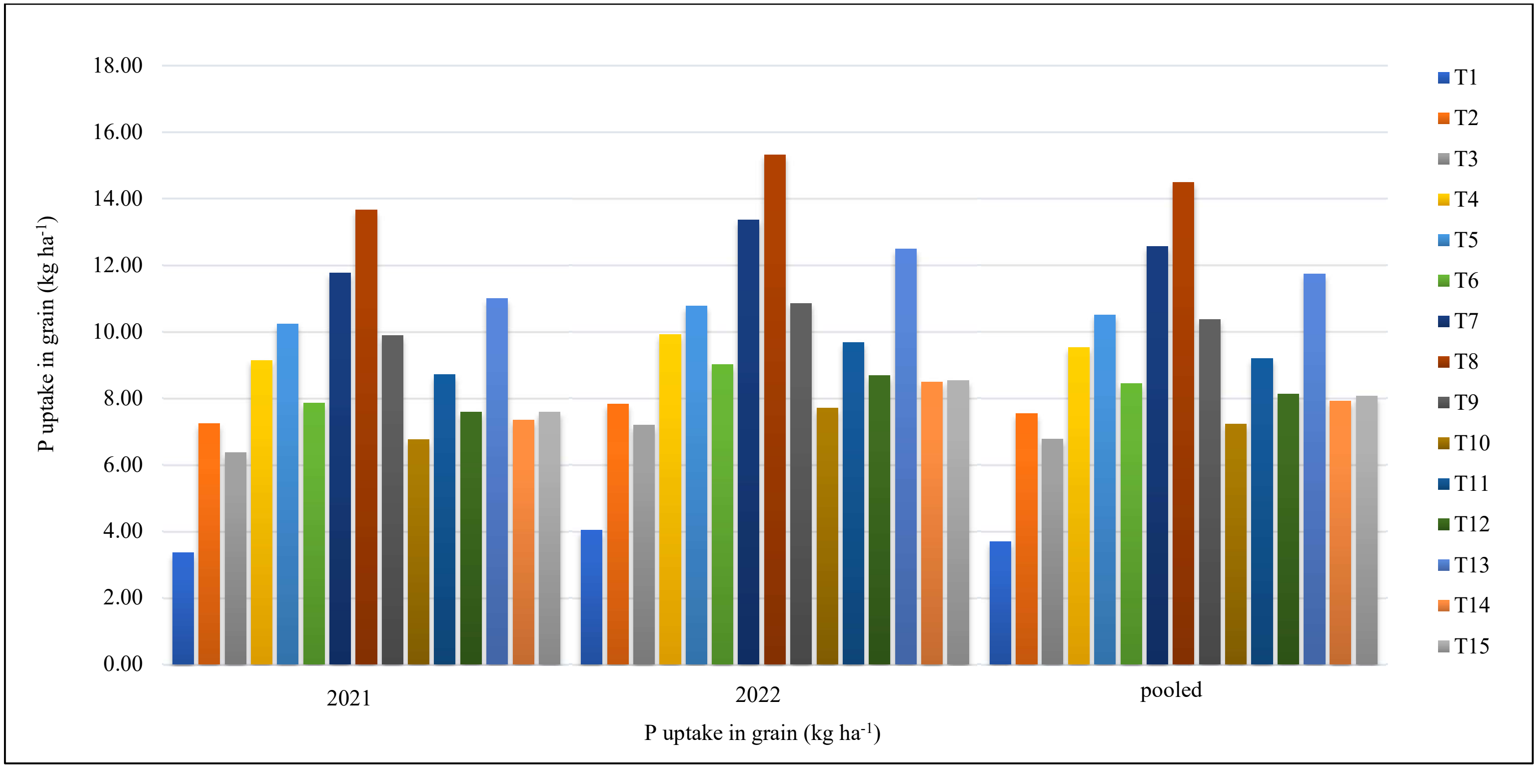


Fig 4.14: Effect of soil fertility management on P uptake in grain (kg ha^{-1}) in direct-seeded rice

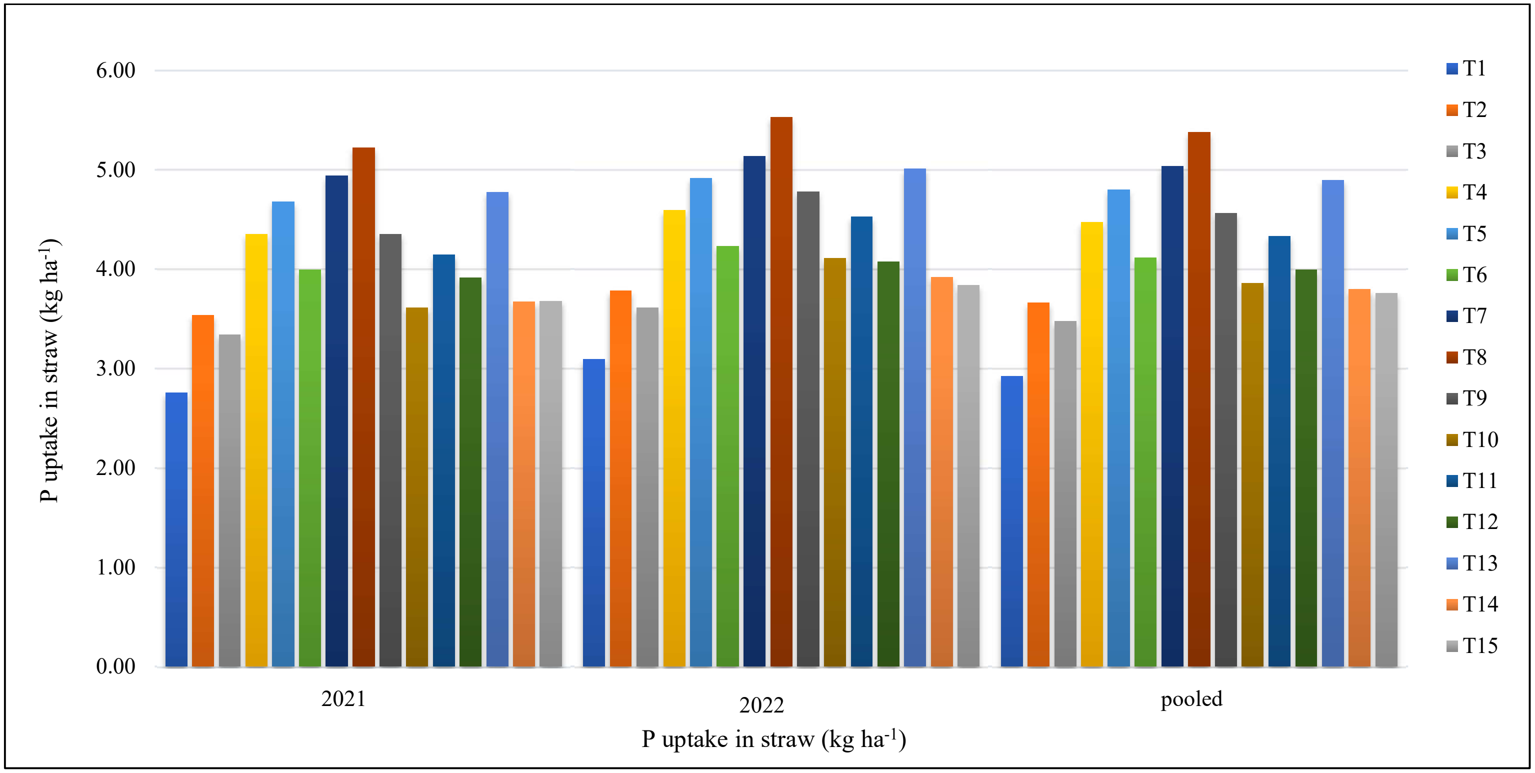


Fig 4.15: Effect of soil fertility management on P uptake in straw (kg ha^{-1}) in direct-seeded rice

4.2.12 K uptake in grain and straw (kg ha^{-1})

The results on potassium uptake in grain and straw of direct seeded rice have been presented in table 4.13 and depicted in fig 4.16 and fig 4.17.

The data recorded showed that the highest potassium uptake in grain was reported with the treatment T_8 for both the years of experimentation with 20.98 kg ha^{-1} and 22.06 kg ha^{-1}, meanwhile the pooled value recorded about 21.52 kg ha^{-1}. The minimum was recorded in control T_1 with 6.64 kg ha^{-1} and 6.99 kg ha^{-1} for both the years 2021 and 2022 with a pooled value of 6.81 kg ha^{-1} respectively. A critical examination of potassium uptake in grain revealed that T_8 was significantly the highest which was followed by T_7 and T_{13} respectively while from the pooled data it was found that T_7 was at par with T_{13}. Further from the pooled data, it reflected that application of T_8 enhanced the potassium uptake in grain by 216.00% over control T_1. Similarly, for potassium uptake in straw the same trend was recorded in treatment T_8 which obtained significantly the highest among all the other treatments with a value of 80.80 kg ha^{-1} and 85.53 kg ha^{-1} for both the years of experimentation and a pooled value of 83.16 kg ha^{-1} respectively, while the lowest was gain recorded in control treatment T_1 with 43.91 kg ha^{-1} and 46.12 kg ha^{-1} for 2021 and 2022 with pooled value of 45.02 kg ha^{-1}, respectively. Treatment T_8 showed an increment of potassium uptake in straw with about 84.71% over control T_1, 6.93% over T_7, 9.50% over T_{13} from the pooled data.

The results show that the uptake in straw was higher as compared to uptake in grain. In general, potassium uptake by leaf and petiole increases till reproductive stage and then decreases when it reaches maturity stage, which implied the more translocation of potassium to grain (Shamima and Hug, 2002). Increase is dry matter is attributable to increase uptake of potassium therefore stem serves as a large reservoir for potassium throughout the growth cycle (Islam *et al*., 2006). In this study it was observed that potassium uptake in straw was higher than grain. This finding was in conformity with Saleque *et al*. (1998), Islam *et al*. (2016) and Kabir *et al*. (2011). The increased in uptake of potassium as documented by Biswas *et al*. (2020) with integrated approach showed better growth of roots which finally gave higher amount of nutrients from the soil thus resulted in better uptake by the plants.

4.2.13 S uptake in grain and straw (kg ha^{-1})

Perusal data of the sulphur uptake in grain and straw had been given in table 4.13 and graphically displayed in fig 4.18 and fig 4.19.

It was evident from the data given that application of treatment T_8 significantly influenced the sulphur uptake in grain for both the years of experimentation with values 22.57 kg ha^{-1} and 24.20 kg ha^{-1} for 2021 and 2022 with pooled value of 23.39 kg ha^{-1}, while the lowest was recorded with control T_1 which had no application of any nutrients with 5.61 kg ha^{-1} and 5.96 kg ha^{-1} for 2021 and 2022 and poled value 5.79 kg ha^{-1} respectively. A critical examination of the pooled dates conveyed that application of treatment T_8 enhanced the S uptake in grain to an extend of 303.97% over control T_1, 9.14% over T_7 and 42.97% over T_6 where both T_7 and T_6 had sulphur application. Meanwhile for sulphur uptake in straw, it was observed that T_8 reported highest with 14.29 kg ha^{-1} and 15.43 kg ha^{-1} for both years of experimentation while the lowest was recorded in control T_1 with 6.68 kg ha^{-1}, and 7.48 kg ha^{-1} for both years of experimentation respectively. Further evaluation from the pooled data revealed that T_8 recorded significantly highest followed by T_7, T_9, T_{11}, T_5, T_6, T_{12} and T_{13}. Comparison among the treatments shows that T_7 was at par with T_9 and T_{11}, and T_9 was at par with T_5 and T_{11} also T_5 was at par T_6, T_{12} and T_{13} for sulphur uptake in straw of rice crop.

Combined application of N, P, K, S, Zn and FYM proved to have higher sulphur uptake both in grain and straw during the two years of experimentation. Exclusion of any of the nutrient or FYM showed a decrease in sulphur uptake as N plays an important role in S accumulation and its omission can lead to decrease in S content thus its uptake (Dash *et al*., 2015). Deletion of S led to

Table 4.13: Effect of soil fertility management on K and S uptake in grain and straw in direct seeded rice

Treatments	K uptake (kg ha^{-1})						S uptake (kg ha^{-1})					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	Pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	6.64	6.99	6.81	43.91	46.12	45.02	5.61	5.96	5.79	6.68	7.48	7.08
T_2- 100% NPK	11.31	11.82	11.56	53.73	57.85	55.79	8.66	9.05	8.86	9.73	10.26	10.00
T_3- 50% NPK	10.10	10.57	10.34	51.58	55.30	53.44	11.02	11.65	11.33	8.79	9.36	9.08
T_4- SSNM (109:30:46 NPK)	15.16	15.67	15.41	67.94	72.43	70.19	16.53	17.50	17.02	10.42	11.43	10.93
T_5- 100% NPK + Zn	16.99	17.73	17.36	72.67	76.73	74.70	18.07	19.23	18.65	11.84	11.65	11.74
T_6- 100% NPK + S	13.82	14.70	14.26	62.28	66.13	64.20	15.72	17.00	16.36	11.16	11.86	11.51
T_7- 100% NPK +Zn + S	18.37	19.64	19.01	76.98	79.34	78.16	20.59	22.26	21.43	12.98	13.90	13.44
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	20.98	22.06	21.52	80.80	85.53	83.16	22.57	24.20	23.39	14.29	15.43	14.86
T_9- 100% NPK + Liming @LR	16.00	16.74	16.37	68.06	74.51	71.29	14.58	15.79	15.18	12.16	13.35	12.75
T_{10}- 50% NPK + Azospirillum	11.31	12.21	11.76	55.46	64.29	59.87	14.10	15.25	14.68	9.86	11.21	10.54
T_{11}- 50% NPK + 50% N-FYM	14.21	15.31	14.76	64.68	70.54	67.61	13.85	15.16	14.51	11.33	12.69	12.01
T_{12}- 50% NPK + 50% N- VC	12.41	13.43	12.92	60.78	63.60	62.19	13.21	14.21	13.71	10.73	11.95	11.34
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	17.48	18.97	18.23	74.24	77.65	75.94	16.50	18.27	17.38	10.93	11.29	11.11
T_{14}- FYM @ 10 t ha^{-1}	12.28	13.58	12.93	56.50	61.04	58.77	12.40	12.49	12.45	8.72	10.49	9.60
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	12.05	13.13	12.59	57.29	60.12	58.71	11.61	11.84	11.72	8.88	9.63	9.26
SEm±	0.46	0.39	0.30	0.45	0.67	0.40	0.41	0.36	0.27	0.52	0.63	0.41
CD(p=0.05)	1.34	1.14	0.86	1.31	1.94	1.14	1.18	1.05	0.77	1.51	1.82	1.16

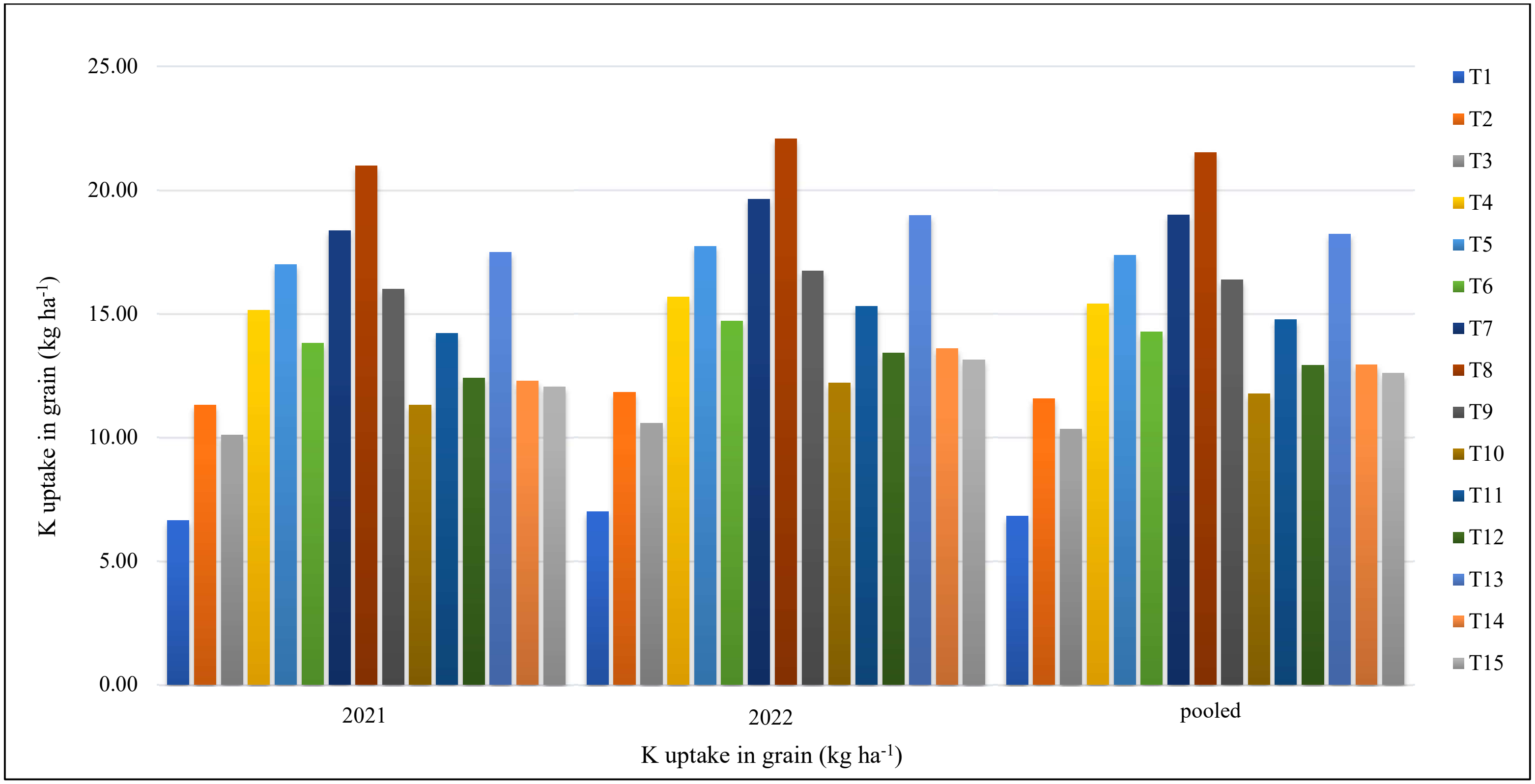


Fig 4.16: Effect of soil fertility management on K uptake in grain (kg ha^{-1}) in direct-seeded rice

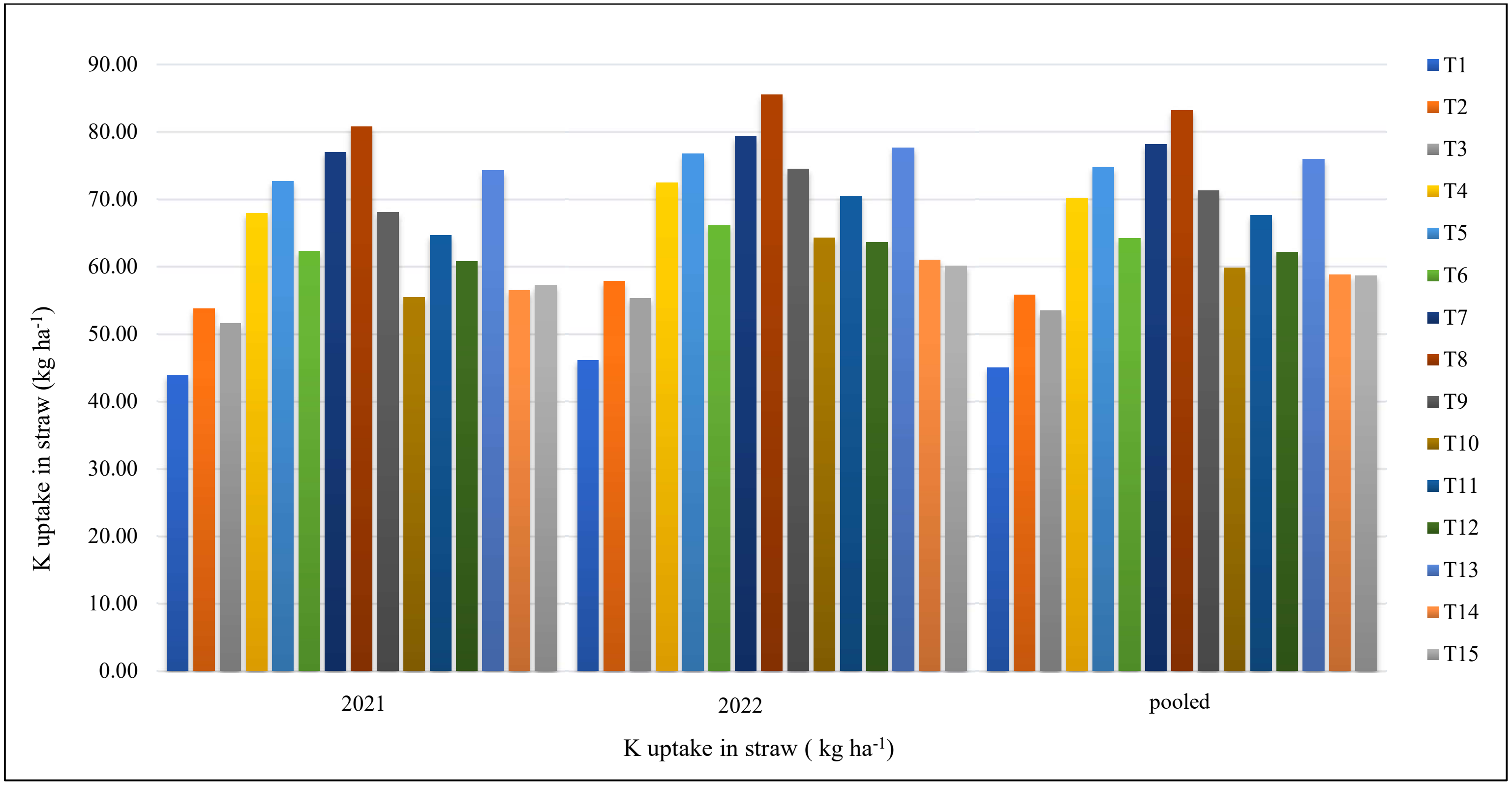


Fig 4.17: Effect of soil fertility management on K uptake in straw (kg ha^{-1}) in direct-seeded rice

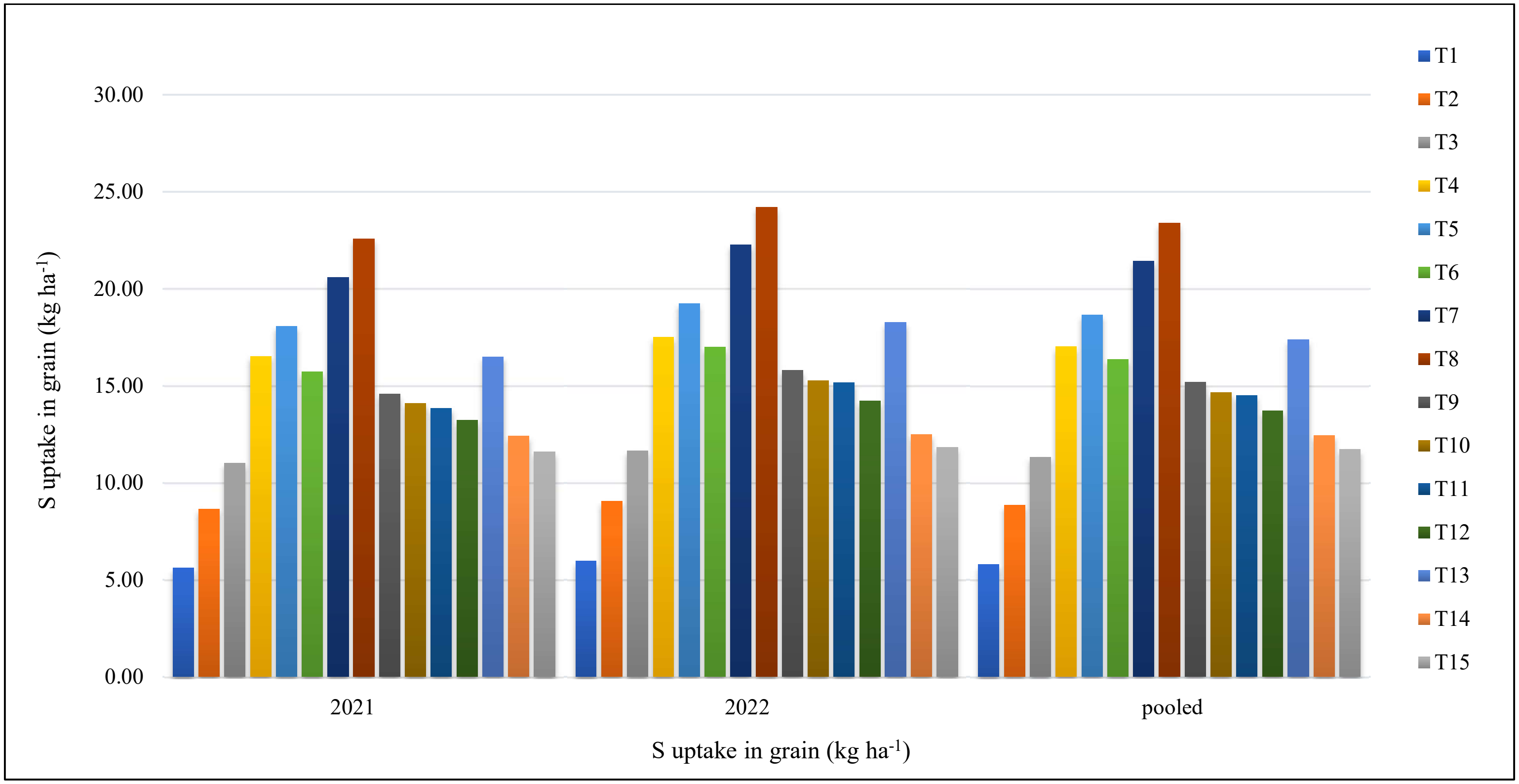


Fig 4.18: Effect of soil fertility management on S uptake in grain (kg ha^{-1}) in direct-seeded rice

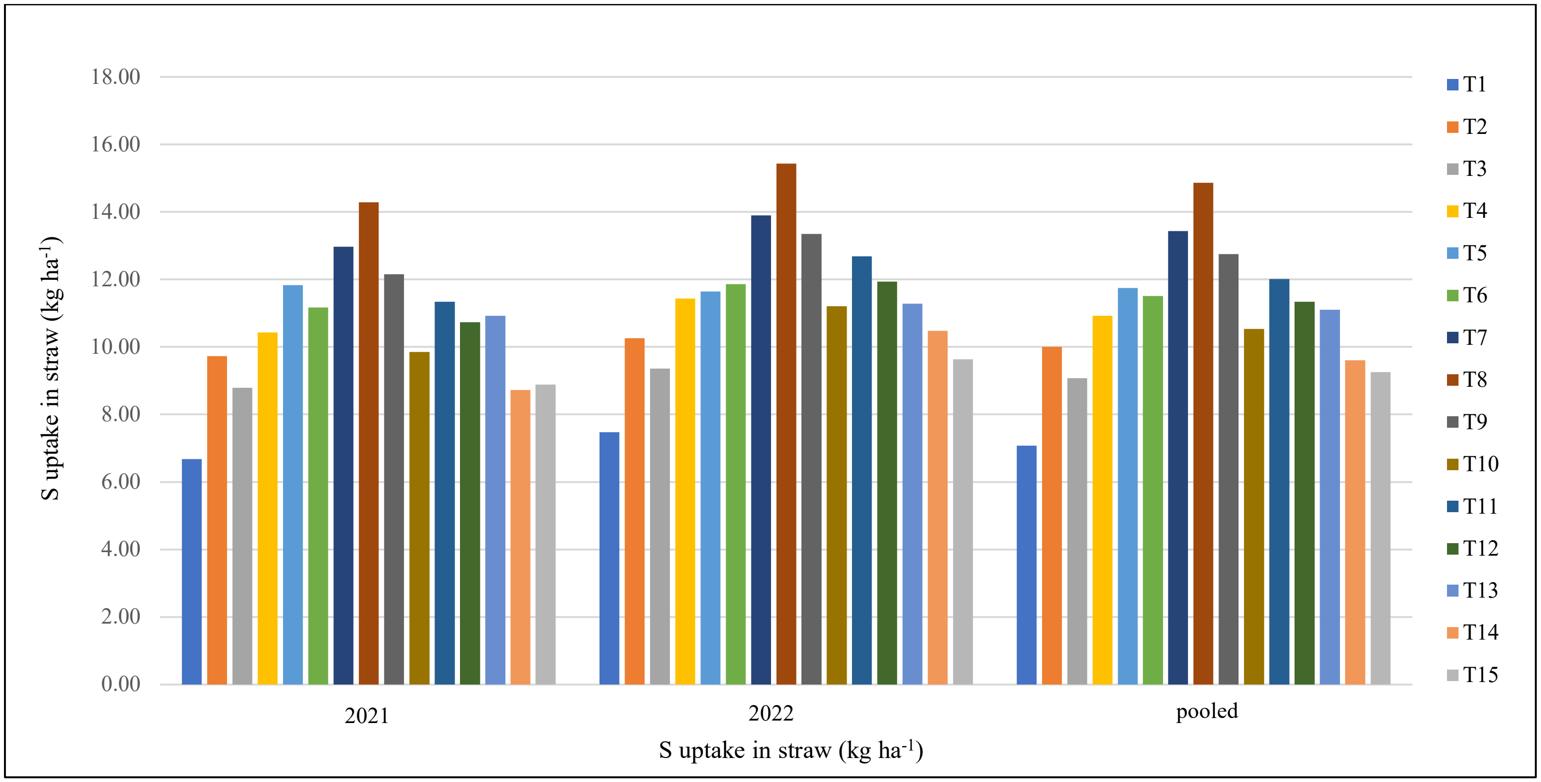


Fig 4.19: Effect of soil fertility management on S uptake in straw (kg ha^{-1}) in direct-seeded rice

decrease in sulphur accumulation in the crop while the deletion of Zn resulted in lower sulphur uptake as zinc plays an important role in S absorption. These results are in conformity with Dash *et al*. (2015) who reported that skipping N, P, K application resulted in decrease of S uptake by the crop. Increase in sulphur uptake by rice crop might be due to the increase availability of sulphur in soil due to its application. Another reason for increase in uptake with S application could be ascribed to increase in grain and straw yield (Ram *et al*., 2014). Sulphur has a synergistic effect on yield and S uptake of the crop at successive stages and exclusion of sulphur had the lowest sulphur uptake (Shamima and Hug, 2002). The higher uptake of sulphur in grain and straw were recorded in the combined application of fertilizers and organic manures compared to chemical fertilizer or organic manures alone. The results are in conformity with Sahu *et al*. (2020). FYM addition increased sulphur uptake as organic matter provided inherent sulphur (Garnaik *et al*., 2022).

4.2.14 Ca uptake in grain and straw (kg ha^{-1})

The data pertaining to calcium uptake in grain and straw of direct seeded rice as influenced by the different treatments under study in soil fertility management has been presented in table 4.14 and displayed in fig 4.20 and fig 4.21.

From the data obtained it was evident that the maximum calcium uptake in grain and straw was recorded with the application of treatment T_8 in both years of experimentation. In grain, treatment T_8 recorded a calcium uptake of 4.29 kg ha^{-1} and 4.12 kg ha^{-1} for 2021 and 2022 with pooled value 4.20 kg ha^{-1} whereas in straw, it recorded about 63.87 kg ha^{-1} and 68.36 kg ha^{-1} for 2021 and 2022 with a pooled value of 66.12 kg ha^{-1}, respectively. While the minimum uptake in grain and straw was observed in control T_1 with 1.15 kg ha^{-1} and1.27 kg ha^{-1} with pooled value 1.21 kg ha^{-1} for grain and 40.98 kg ha^{-1} and 43.50 kg ha^{-1} with pooled value 42.24 kg ha^{-1} for straw, respectively. A critical examination of the treatments showed that in grain, calcium uptake T_8 was at par with T_7, while T_7

at par with T_5, T_9 and T_{13} respectively. Treatment T_8 recorded a significant increase to an extent of about 247.10% over the control T_1. Whereas the calcium uptake in straw for the year 2021, T_8 was at par with T_7 while T_7 also found to be at par with T_5 and T_{13} respectively. In the year 2022, T_7 was recorded to be at par with T_5, T_9 and T_{13}. The calcium uptake in straw with treatment T_8 was increased to an extend of 56.53% over control T_1.

Uptake of nutrients in grain and straw was also greatly influenced by the secondary and micronutrients along with macronutrients and organic manures. When nutrients were applied as per need basis it resulted in balanced fertilization and increased absorption of other nutrients (Rani and Latha. 2017). They further reported that the uptake of calcium in grain and straw established a significant and positive correlation with yield of the crop. The highest calcium uptake both in grain and straw with treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) in this study are in similarity with Puli *et al*. (2017) recording the highest Ca uptake with the treatments receiving FYM @ 10 t ha^{-1} + RDF. Chander *et al*. (2007) also observed that incorporation of FYM resulted in a significant increase in Ca uptake by cauliflower which may be interpreted in terms of its effect in improvement in soil exchangeable Ca.

4.2.15 Zn uptake in grain and straw (g ha^{-1})

The results for zinc uptake in grain and straw of direct seeded rice by the different treatments under study are depicted in the table 4.14 and figuratively presented in fig 4.22 and fig 4.23.

From the data obtained it became evident that zinc uptake both in grain and straw were significantly higher with treatments which had nutrient application except for control which had no nutrients application. The maximum zinc uptake in grain was observed in treatment T_8 recording 144.66 g ha^{-1} and 150.44 g ha^{-1} for both years of experimentation with pooled value of 147.55 g ha^{-1} while lowest was recorded in control T_1 with 60.92 g ha^{-1} and 62.53 g ha^{-1}

Table 4.14: Effect of soil fertility management on Ca and Zn uptake in grain and straw in direct seeded rice

Treatments	Ca uptake (kg ha^{-1})						Zn uptake (g ha^{-1})					
	Grain			Straw			Grain			Straw		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	1.15	1.27	1.21	40.98	43.50	42.24	60.92	62.53	61.73	169.90	175.57	172.74
T_2- 100% NPK	1.96	2.32	2.14	49.66	53.74	51.70	92.39	93.61	93.00	204.47	215.90	210.18
T_3- 50% NPK	1.71	2.08	1.89	47.70	52.01	49.85	85.15	87.77	86.46	196.15	209.23	202.69
T_4- SSNM (109:30:46 NPK)	2.76	2.70	2.73	55.97	60.42	58.20	109.56	112.57	111.06	241.09	251.10	246.10
T_5- 100% NPK + Zn	2.96	3.18	3.07	59.20	62.41	60.80	119.64	123.19	121.41	254.21	262.92	258.57
T_6- 100% NPK + S	2.26	2.57	2.42	53.55	57.28	55.42	105.74	108.77	107.25	231.67	242.41	237.04
T_7- 100% NPK +Zn + S	3.67	3.67	3.67	61.18	64.04	62.61	133.81	140.25	137.03	261.86	268.46	265.16
T_8- 100% NPK +Zn +S + FYM @5t ha^{-1}	4.29	4.12	4.20	63.87	68.36	66.12	144.66	150.44	147.55	271.93	286.30	279.11
T_9- 100% NPK + Liming @LR	3.00	2.95	2.97	56.94	61.35	59.15	115.48	119.06	117.27	237.43	253.43	245.43
T_{10}- 50% NPK + Azospirillum	2.15	2.47	2.31	51.23	58.68	54.96	91.91	96.08	94.00	200.62	228.54	214.58
T_{11}- 50% NPK + 50% N-FYM	2.82	2.68	2.75	54.89	59.84	57.37	106.82	111.33	109.07	230.38	246.54	238.46
T_{12}- 50% NPK + 50% N- VC	2.30	2.77	2.53	54.22	55.89	55.05	97.91	102.77	100.34	222.92	229.89	226.40
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	3.53	3.71	3.62	60.24	63.20	61.72	121.09	127.62	124.36	250.11	258.54	254.32
T_{14}- FYM @ 10 t ha^{-1}	2.07	2.59	2.33	51.03	54.96	52.99	98.28	101.16	99.72	205.10	218.23	211.67
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	2.28	2.17	2.23	49.50	51.76	50.63	93.57	98.26	95.91	197.62	203.63	200.62
SEm±	0.24	0.31	0.20	1.19	0.98	0.77	3.14	3.90	2.50	8.56	7.70	5.76
CD(p=0.05)	0.71	0.89	0.55	3.45	2.85	2.19	9.09	11.31	7.09	24.79	22.31	16.31

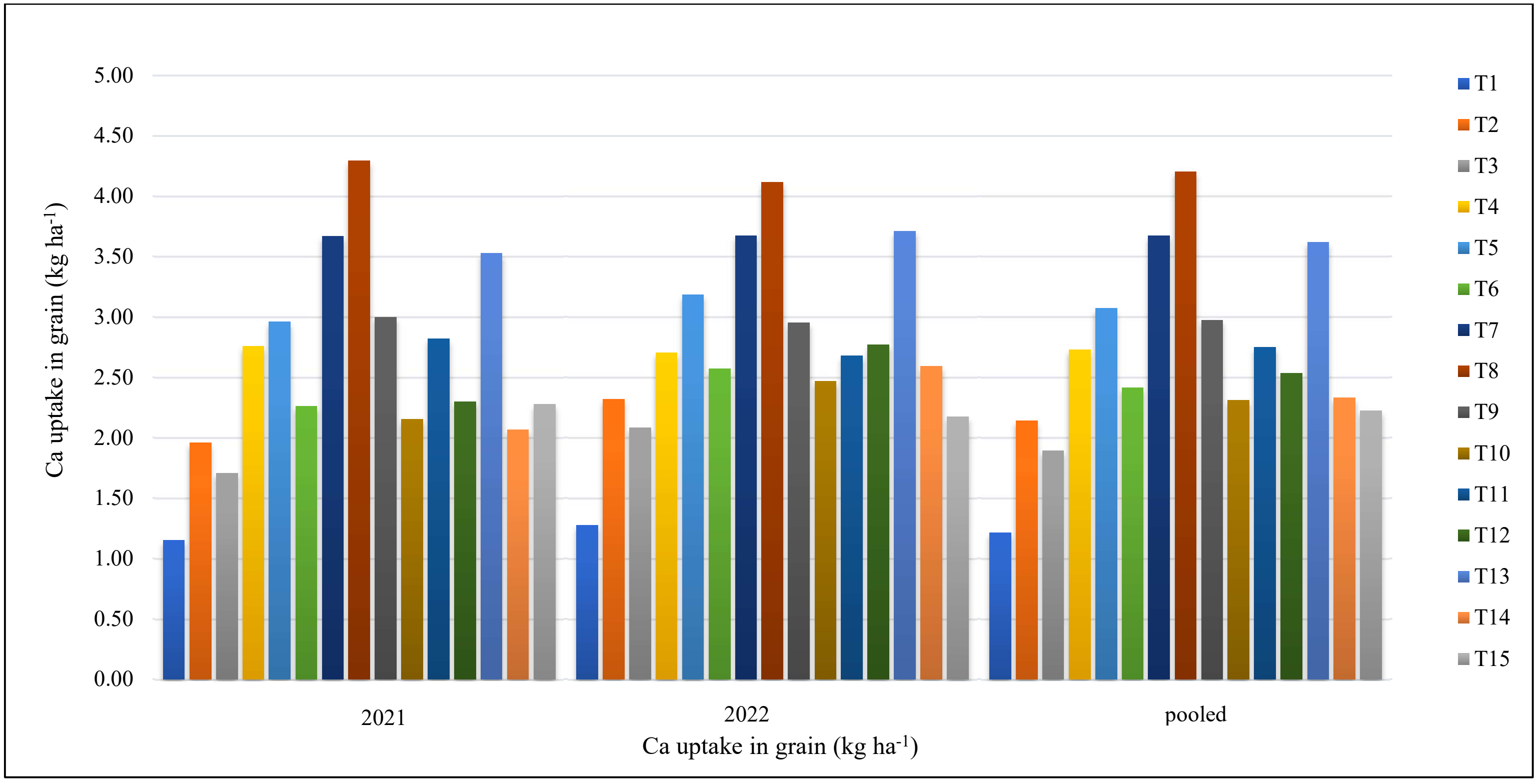


Fig 4.20: Effect of soil fertility management on Ca uptake in grain (kg ha^{-1}) in direct-seeded rice

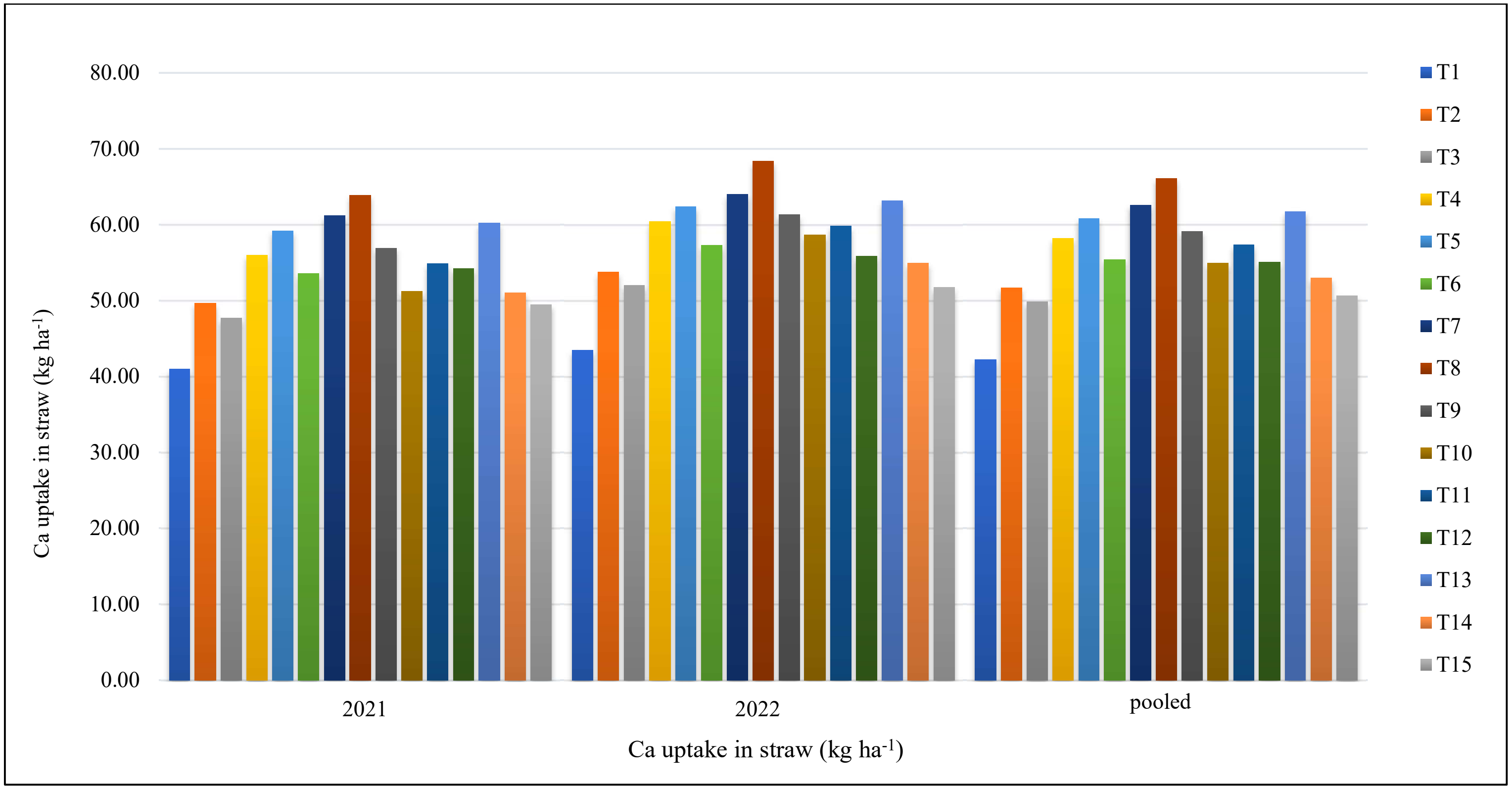


Fig 4.21: Effect of soil fertility management on Ca uptake in straw (kg ha^{-1}) in direct-seeded rice

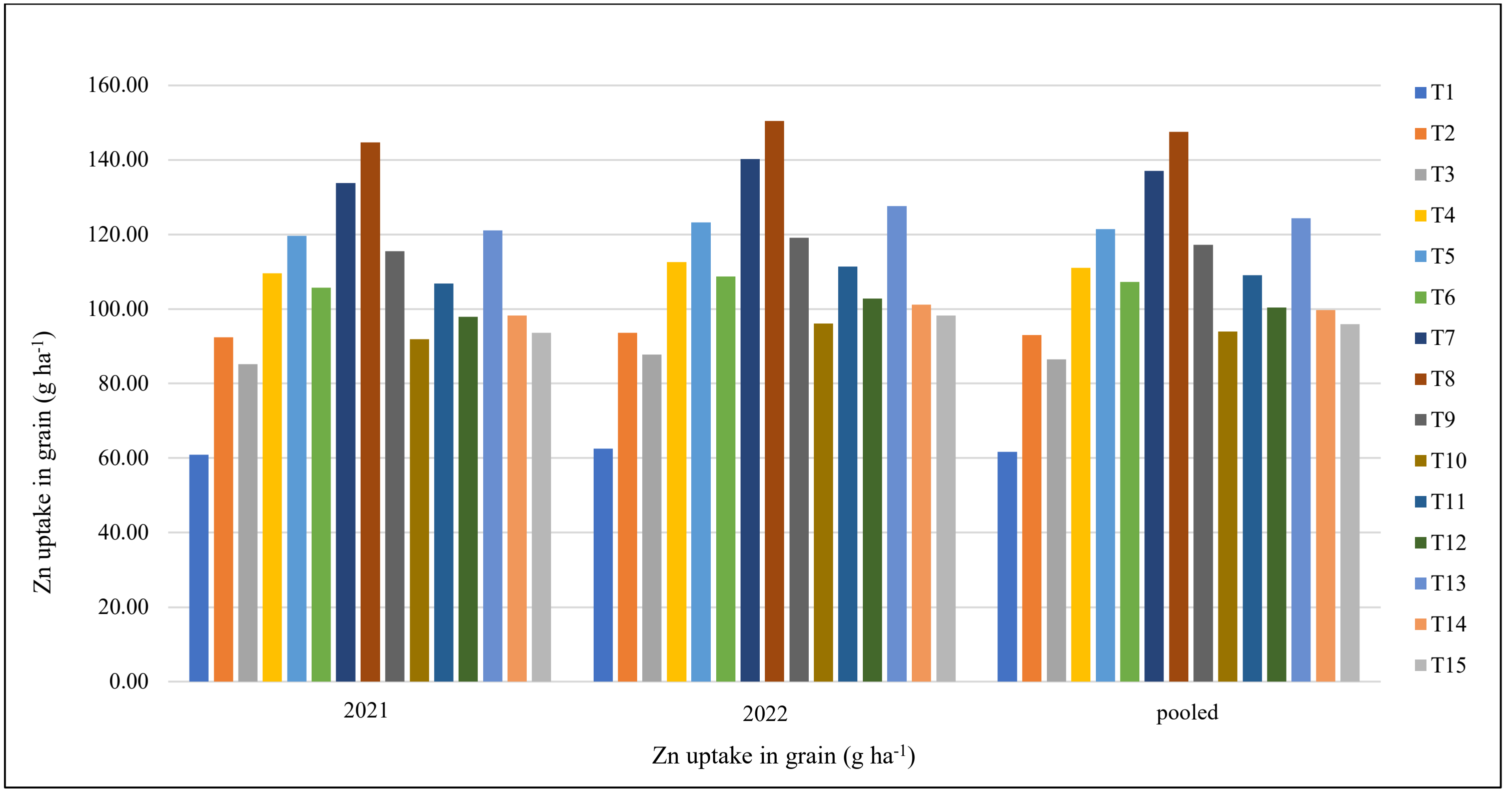


Fig 4.22: Effect of soil fertility management on Zn uptake in grain (g ha^{-1}) in direct-seeded rice

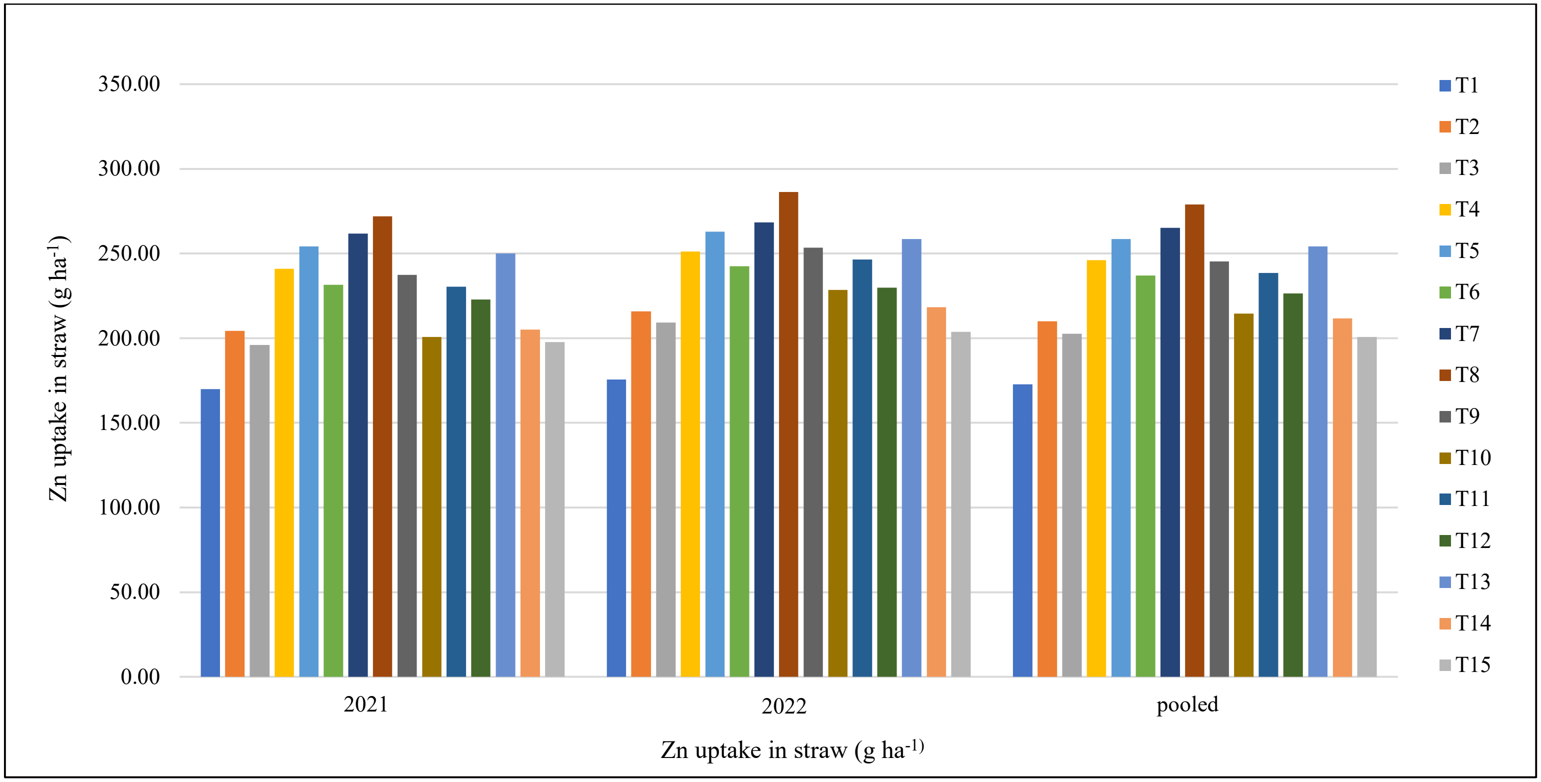


Fig 4.23: Effect of soil fertility management on Zn uptake in straw (g ha^{-1}) in direct-seeded rice

with pooled value 61.73 g ha^{-1} respectively. Further evaluation from the pooled data revealed that T_8 was followed by T_7 (137.03 g ha^{-1}) and T_{13} (124.26 g ha^{-1}) where T_{13} was also reported to be at par with T_5 (121.41 g ha^{-1}) and T_9 (117.27 g ha^{-1}). Treatment T_8 recorded an increased zinc uptake in grain of about 139.02% over control. Similarly in straw uptake of zinc, treatment T_8 recorded significantly the highest (237.43 g ha^{-1} and 253.43 g ha^{-1} with pooled value 245.43 g ha^{-1}) among all the treatments while the lowest in control T_1 with 169.90 g ha^{-1} and 175.57 g ha^{-1} for 2021 and 2022, with pooled value 172.74 g ha^{-1} respectively. A critical examination among the treatments from the pooled data conveyed that treatment T_8 was at par with T_7 (265.16 g ha^{-1}), while T_7 was also at par with T_5 (258.57 g ha^{-1}) and T_{13} (254.32 g ha^{-1}). Zinc uptake in straw with treatment T_8 was enhanced to an extend of 61.57% over control T_1.

The increase in nutrient uptake could be attributed to application of zinc to plants which in turn provided vigorous growth resulting in greater absorption of nutrients from the soil (Kumar *et al*., 2017). Combined application of N, P, K, S, Zn along with FYM provided the highest zinc uptake. This result corroborates with the findings of Dash *et al*. (2015) who reported that omission of any nutrient N, P, K, S or Zn resulted a lower accumulation of the nutrients over control. Integrated use of both major and micronutrient recorded highest zinc absorption. The interaction effect of P and Zn is synergistic. Rahman *et al*. (2008) also reported that application of full recommended dose of sulphur and zinc increased the zinc uptake by the crop. Balanced fertilization significantly and consistently increased the uptake of crop but combination with organic source FYM proved its superiority with respect to nutrient uptake in comparison to other treatments due to more availability of nutrients caused be solubilization of nutrients from insoluble sources from organic manure due to release of organic acids and improvement in soil physico-chemical properties and biological environment. These results are in accordance with Kumar *et al*. (2018) and Lakshmi *et al*. (2015).

4.2.16 Fe uptake in grain and straw (g ha^{-1})

The data pertaining to iron uptake in grain and straw of direct seeded rice under different treatments under study has been arranged in table 4.15 and graphically depicted in fig 4.24 and fig 4.25.

Perusal data of iron uptake in grain showed that treatment T_8 recorded the maximum iron uptake with 279.27 g ha^{-1} and 289.49 g ha^{-1} for both years of experimentation and with a pooled value 284.38 g ha^{-1} while the minimum was recorded in control T_1 with 126.92 g ha^{-1} and 130.19 g ha^{-1} with pooled value 128.55 g ha^{-1} respectively. Treatment T_8 showed significantly the highest which recorded an increased in grain uptake to an extend of 125.19% over control. Similarly, the iron uptake in straw was also recorded in treatment T_8 with 595.71 g ha^{-1} and 625.79 g ha^{-1} for 2021 and 2022 with pooled value of 610.75 g ha^{-1} whereas the minimum recorded in control T_1 with 396.93 g ha^{-1} and 409.58 g ha^{-1} with pooled value of 403.25 g ha^{-1} respectively. Critical evaluation of the treatments in pooled data revealed that treatment T_7 (580.56 g ha^{-1}) was at par with T_{13} (567.12 g ha^{-1}). Straw uptake with treatment T_8 showed an increment of about 51.45% over control T_1.

The treatments which received organic sources along with inorganic fertilizers proved to have a surpassing iron uptake over the treatments which only received recommended dose of fertilizer alone or organic sources alone. The results are in agreement with Sriramachandrasekharan (2001) who reported the highest iron uptake with plots which received organic sources. Easy availability of iron in organics during mineralization might have increased its uptake by rice due to increased plant height, leaf area, straw and grain yield (Puli *et al*., 2017).

4.2.17 Mn uptake in grain and straw (g ha^{-1})

The data pertaining to manganese uptake in grain and straw of direct seeded rice under different treatments under study has been presented in table 4.15 and graphically depicted in fig 4.26 and fig 4.27.

Perusal data of manganese uptake in grain showed that treatment T_8 recorded the maximum uptake with 237.91 g ha^{-1} and 246.80 g ha^{-1} for both years of experimentation and with pooled value 242.35 g ha^{-1} while the minimum was recorded in control T_1 with 93.14 g ha^{-1} and 96.42 g ha^{-1} while a pooled value of 94.78 g ha^{-1} respectively. Treatment T_8 was significantly the highest which recorded an increased in grain uptake of manganese to an extend of 155.69% over control. Further evaluation also revealed that T_7 (219.02 g ha^{-1}) was found to be at par with T_{13} (209.55 g ha^{-1}). Similarly, the highest manganese uptake in straw was also recorded in treatment T_8 with 409.90 g ha^{-1} and 430.62 g ha^{-1} for the year 2021 and 2022 with pooled value of 420.26 g ha^{-1} whereas the minimum was recorded in control T_1 with 269.86 g ha^{-1} and 278.92 g ha^{-1} with pooled value of 274.39 g ha^{-1} respectively. Critical evaluation of the treatments in pooled data revealed that treatment T_7 (398.68 g ha^{-1}) was at par with T_5 (385.69 g ha^{-1}) and T_{13} (388.81 g ha^{-1}). Straw uptake with treatment T_8 showed an increment of about 53.16% over control T_1.

Balanced fertilization influenced the availability of nutrients in the sink which encouraged the uptake of nutrients by the crop and in addition the increased availability of N in treatments with organic manures was high which plausibly might have increased the availability of Mn in soil thereby plant uptake. These results were supported by Puli *et al*. (2017) and Das *et al*. (2002) who reported the synergistic interaction between Mn and available N was found to be positive.

4.2.18 Cu uptake in grain and straw (g ha^{-1})

The data regarding manganese uptake in grain and straw of direct seeded rice under different treatments under study has been laid out in table 4.16 and depicted in fig 4.28 and fig 4.29.

It was apparent from the data that the highest copper uptake in grain was observed in treatment T_8 which recorded an uptake of 37.11 g ha^{-1} and 38.92 g ha^{-1} for both years of experimentation with pooled value 38.02 g ha^{-1} while the minimum was recorded in control T_1 with 11.08 g ha^{-1} and 11.51 g ha^{-1} for the both the years 2021 and 2022 with pooled value of 11.30 g ha^{-1} respectively. Treatment T_8 was significantly the highest which recorded an increased in grain uptake to an extend of 236.46% over control. Further evaluation of the data revealed that treatment T_7 (34.93 g ha^{-1}) and T_{13} (31.22 g ha^{-1}) were found to be at par with T_8. The highest copper uptake in straw was also observed with treatment T_8 which recorded 69.29 g ha^{-1} and 72.91 g ha^{-1} for the year 2021 and 2022 with pooled value of 71.10 g ha^{-1} while the minimum copper uptake in straw was recorded in control T_1 with 34.62 g ha^{-1} and 36.12 g ha^{-1} with a pooled value 35.37 g ha^{-1} respectively. Critical evaluation of the treatments in pooled data revealed that treatment T_8 was at par with T_5 (59.65 g ha^{-1}), T_7 (67.02 g ha^{-1}), T_9 (60.49 g ha^{-1}) and T_{13} (62.82 g ha^{-1}). Straw uptake with treatment T_8 showed an increment of about 101.01% over control T_1.

The improved availability of nutrients made possible through different combination of organic and inorganic sources of fertilizers might have encouraged a favorable chemical environment of the root zone thereby encouraging higher root proliferation and ultimately increased nutrient absorption by the rice crop. Puli *et al*. (2017) reported that treatment which received green manuring along with recommended dose of fertilizer gave the highest Ca uptake in rice but was at par with treatment that received FYM @ 10 t ha^{-1}.

Table 4.15: Effect of soil fertility management on Fe and Mn uptake in grain and straw in direct seeded rice

Treatments	**Fe uptake (g ha^{-1})**						**Mn uptake (g ha^{-1})**					
	Grain			**Straw**			**Grain**			**Straw**		
	2021	**2022**	**pooled**	**2021**	**2022**	**pooled**	**2021**	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	126.92	130.19	128.55	396.93	409.58	403.25	93.14	96.42	94.78	269.86	278.92	274.39
T_2- 100% NPK	189.33	190.57	189.95	461.54	486.81	474.18	142.70	144.22	143.46	310.99	328.17	319.58
T_3- 50% NPK	173.53	180.05	176.79	444.62	473.92	459.27	131.04	135.18	133.11	295.11	320.21	307.66
T_4- SSNM (109:30:46 NPK)	217.17	223.12	220.15	529.23	551.56	540.40	174.77	179.63	177.20	360.24	375.60	367.92
T_5- 100% NPK + Zn	226.13	232.16	229.14	554.48	573.41	563.94	189.79	194.74	192.27	379.08	392.29	385.69
T_6- 100% NPK + S	208.20	213.95	211.07	502.80	525.96	514.38	162.03	166.75	164.39	339.72	355.07	347.39
T_7- 100% NPK +Zn + S	256.89	268.24	262.57	573.67	587.45	580.56	214.08	223.97	219.02	393.94	403.42	398.68
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	279.27	289.49	284.38	595.71	625.79	610.75	237.91	246.80	242.35	409.90	430.62	420.26
T_9- 100% NPK + Liming @LR	228.06	234.89	231.47	526.43	562.01	544.22	191.23	197.20	194.22	358.31	381.75	370.03
T_{10}- 50% NPK + Azospirillum	182.37	190.07	186.22	469.99	535.29	502.64	141.28	147.37	144.32	316.22	360.38	338.30
T_{11}- 50% NPK + 50% N-FYM	206.99	215.29	211.14	512.17	546.13	529.15	176.25	183.67	179.96	347.14	371.64	359.39
T_{12}- 50% NPK + 50% N- VC	190.17	199.36	194.76	498.62	513.90	506.26	152.99	159.99	156.49	336.73	350.93	343.83
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	243.11	256.29	249.70	558.20	576.85	567.52	203.92	215.17	209.55	382.44	395.18	388.81
T_{14}- FYM @ 10 t ha^{-1}	199.32	204.90	202.11	473.36	503.48	488.42	156.62	161.14	158.88	318.10	338.57	328.34
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	187.03	196.23	191.63	457.94	471.84	464.89	151.37	159.09	155.23	309.39	319.07	314.23
SEm±	4.48	4.69	3.24	6.85	7.72	5.16	8.01	9.14	6.08	7.29	7.70	5.30
CD(p=0.05)	12.97	13.59	9.19	19.85	22.37	14.62	23.20	26.49	17.22	21.13	22.29	15.02

Table 4.16: Effect of soil fertility management on Cu uptake in grain and straw in direct seeded rice

Treatments	Cu uptake (g ha^{-1})					
	Grain			Straw		
	2021	2022	pooled	2021	2022	pooled
T_1- Control	11.08	11.51	11.30	34.62	36.12	35.37
T_2- 100% NPK	17.97	18.09	18.03	38.98	42.40	40.69
T_3- 50% NPK	16.43	16.91	16.67	36.93	39.83	38.38
T_4- SSNM (109:30:46 NPK)	27.24	28.02	27.63	53.72	56.20	54.96
T_5- 100% NPK + Zn	28.62	29.53	29.07	58.86	60.43	59.65
T_6- 100% NPK + S	24.41	25.18	24.79	51.47	53.18	52.33
T_7- 100% NPK +Zn + S	34.22	35.65	34.93	66.32	67.71	67.02
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	37.11	38.92	38.02	69.29	72.91	71.10
T_9- 100% NPK + Liming @LR	29.26	30.33	29.79	58.61	62.37	60.49
T_{10}- 50% NPK + Azospirillum	18.05	18.65	18.35	43.70	49.07	46.39
T_{11}- 50% NPK + 50% N-FYM	25.08	26.16	25.62	54.43	58.89	56.66
T_{12}- 50% NPK + 50% N- VC	22.65	24.03	23.34	50.18	51.44	50.81
T_{13}- 50% NPK + 25% N-FYM +25% N-VC	30.22	32.21	31.22	63.33	62.30	62.82
T_{14}- FYM @ 10 t ha^{-1}	21.64	22.95	22.29	45.93	48.83	47.38
T_{15}- FYM @ 10 t ha^{-1} + Liming@LR	21.24	22.79	22.02	47.19	48.30	47.75
SEm±	3.48	3.43	2.44	6.26	5.52	4.18
CD(P=0.05)	10.08	9.93	6.92	18.14	16.00	11.83

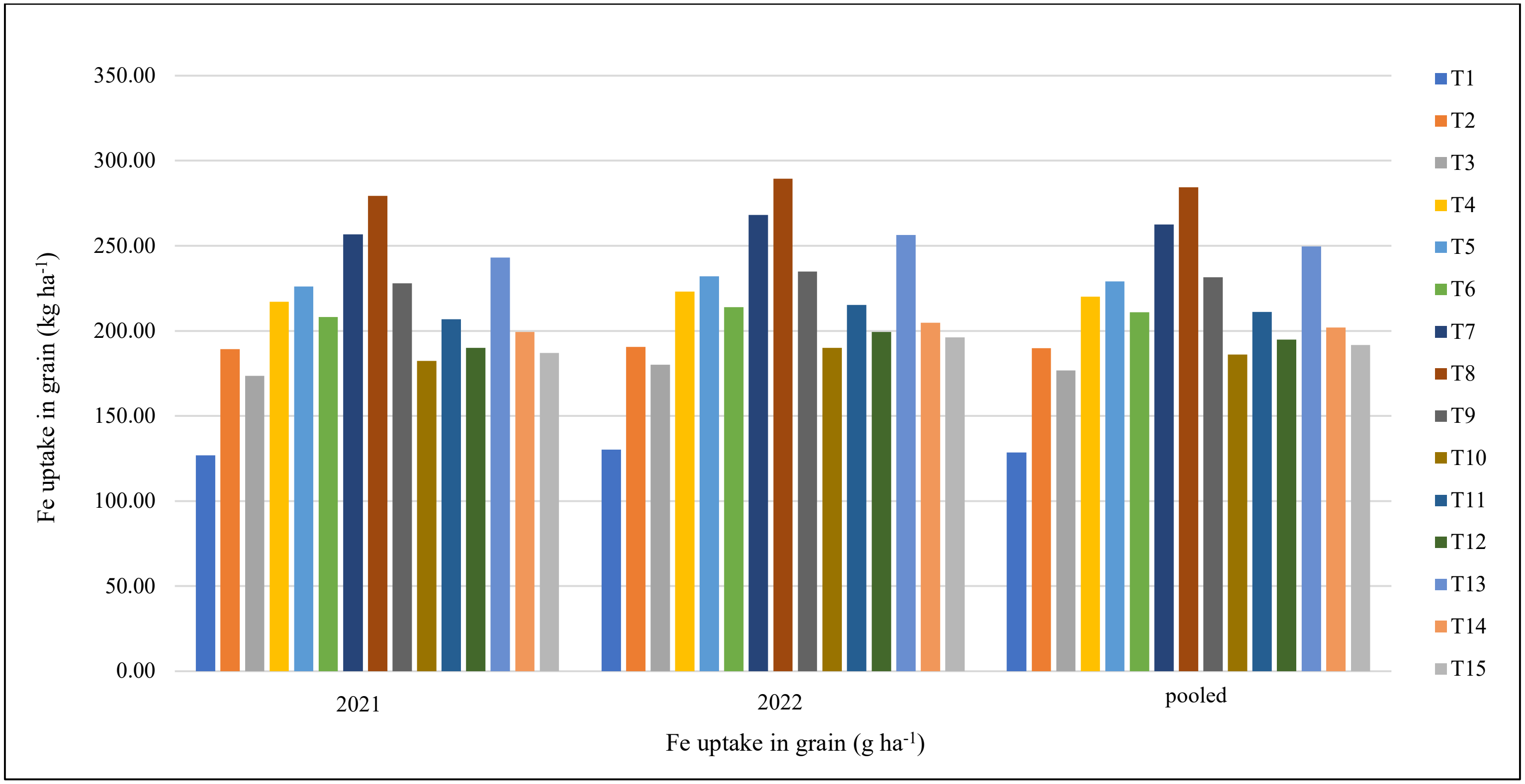


Fig 4.24: Effect of soil fertility management on Fe uptake in grain (g ha^{-1}) in direct-seeded rice

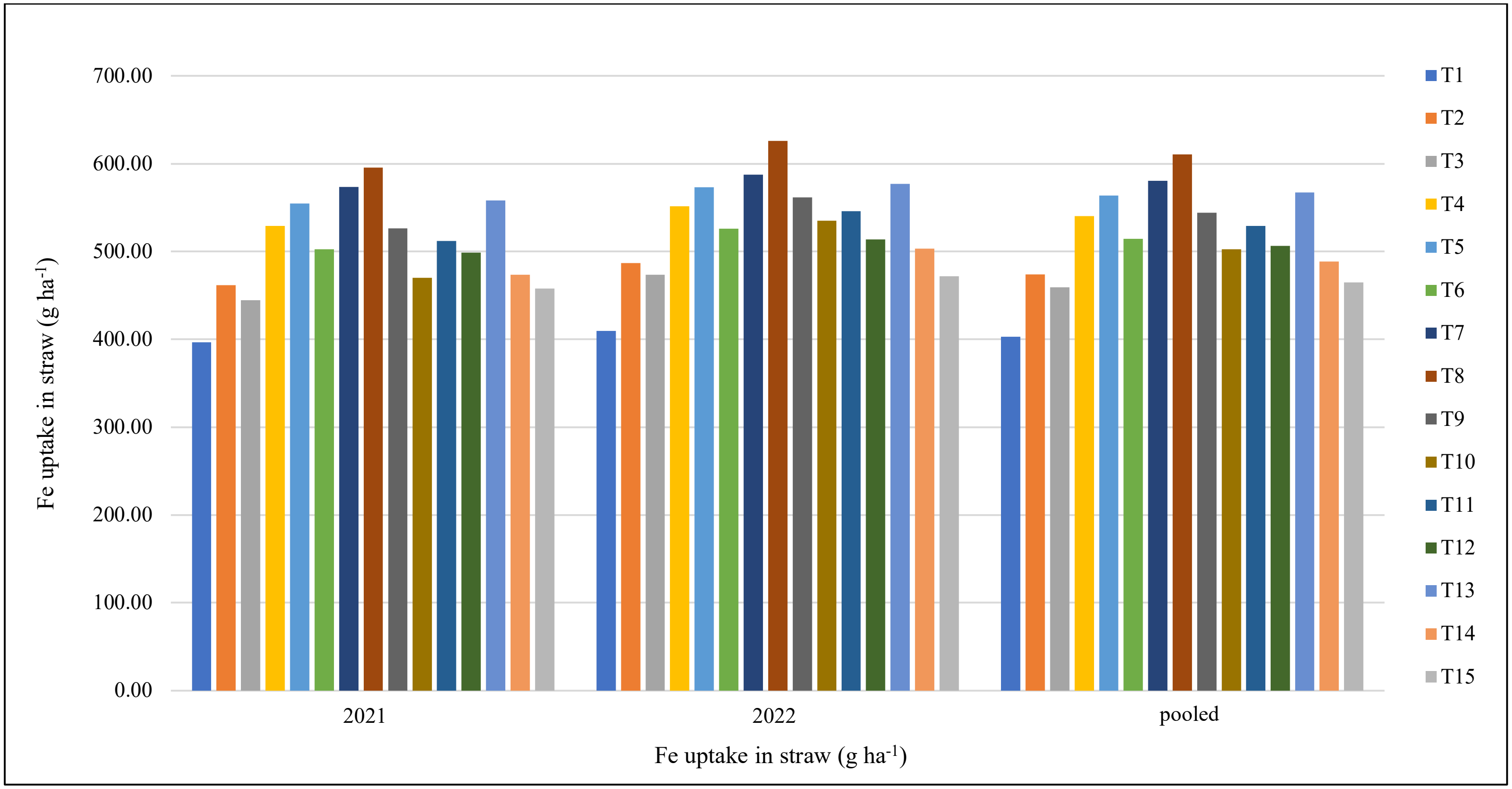


Fig 4.25: Effect of soil fertility management on Fe uptake in straw (g ha^{-1}) in direct-seeded rice

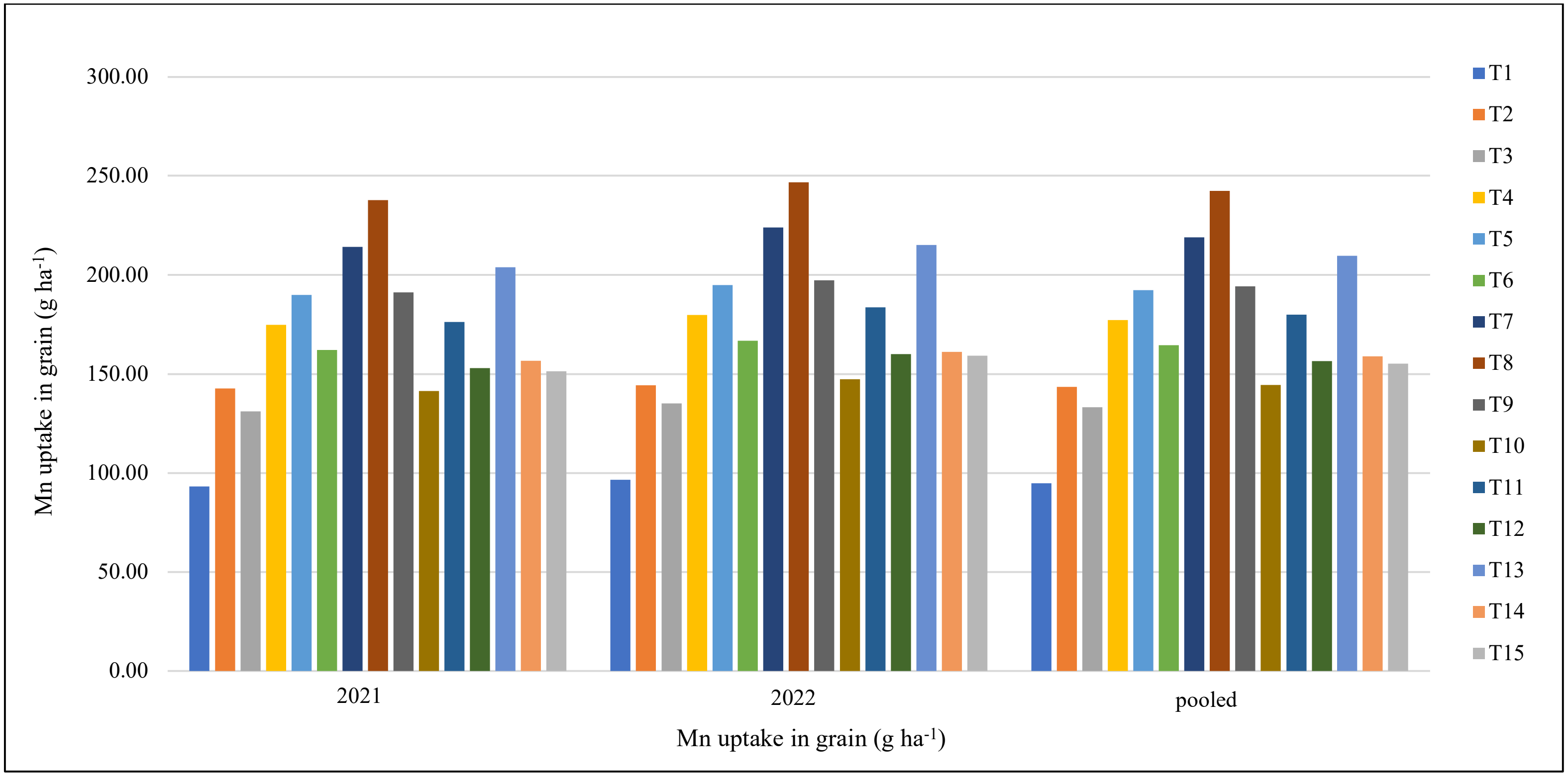


Fig 4.26: Effect of soil fertility management on Mn uptake in grain (g ha^{-1}) in direct-seeded rice

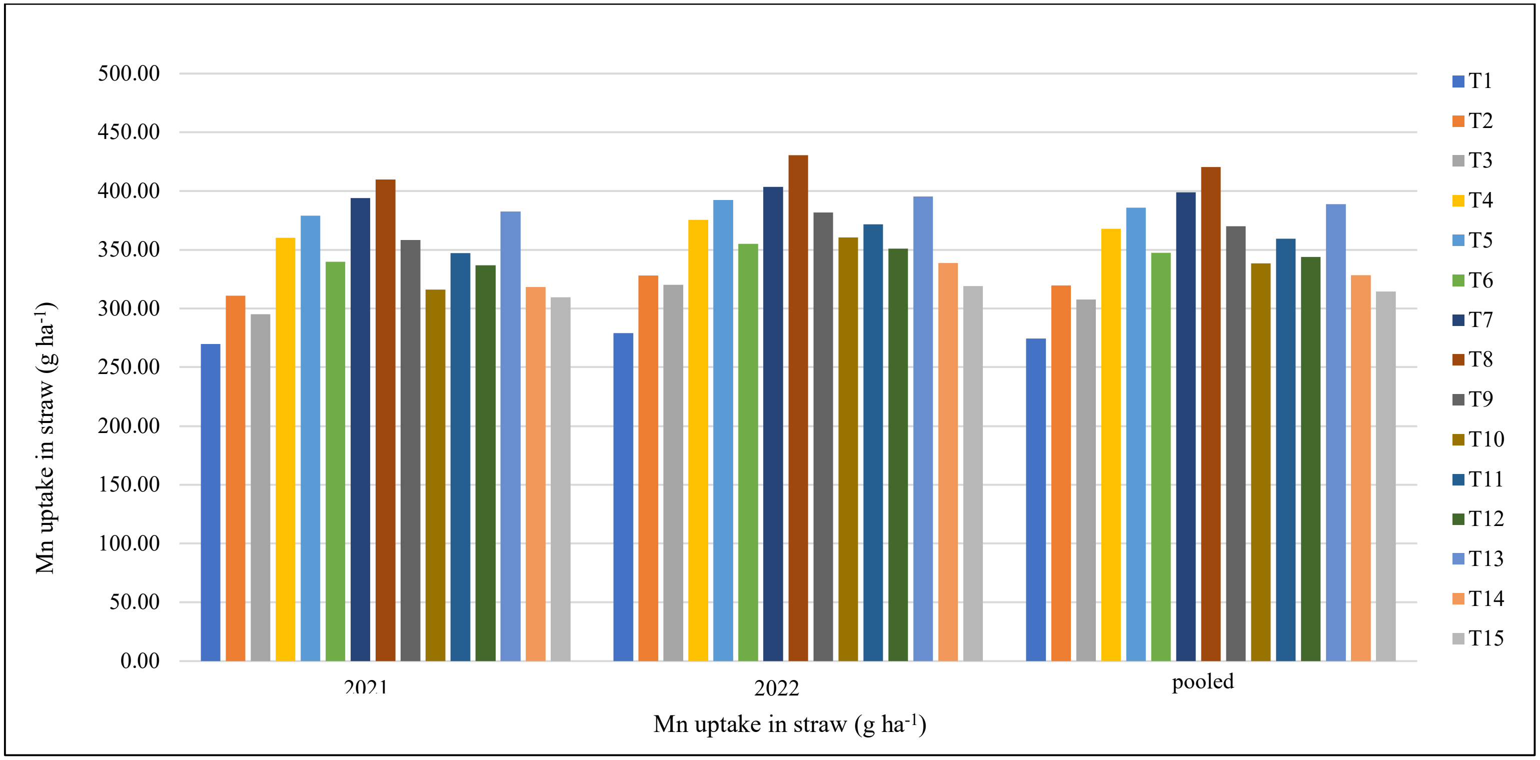


Fig 4.27: Effect of soil fertility management on Mn uptake in straw (g ha^{-1}) in direct-seeded rice

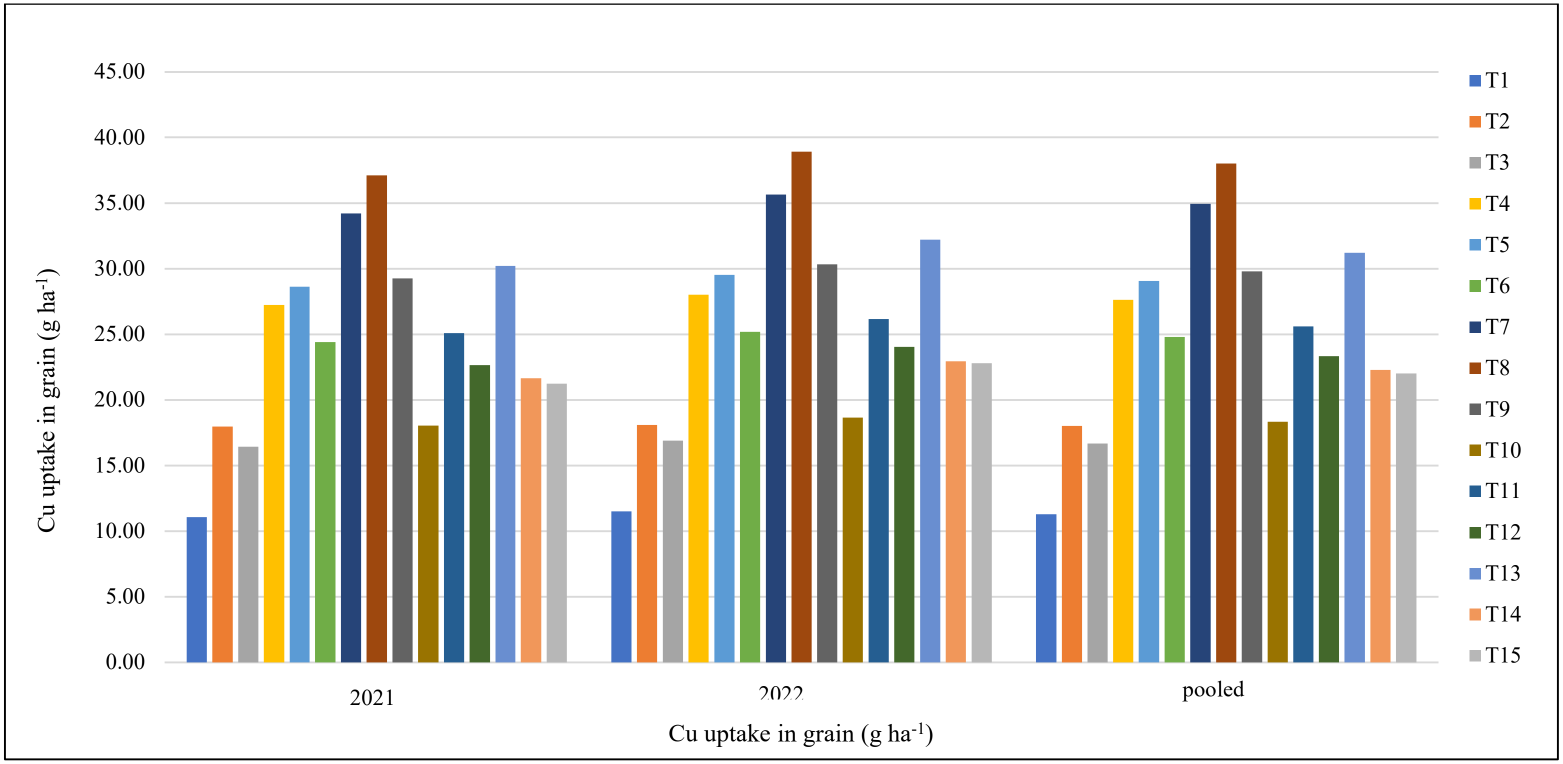


Fig 4.28: Effect of soil fertility management on Cu uptake in grain (g ha^{-1}) in direct-seeded rice

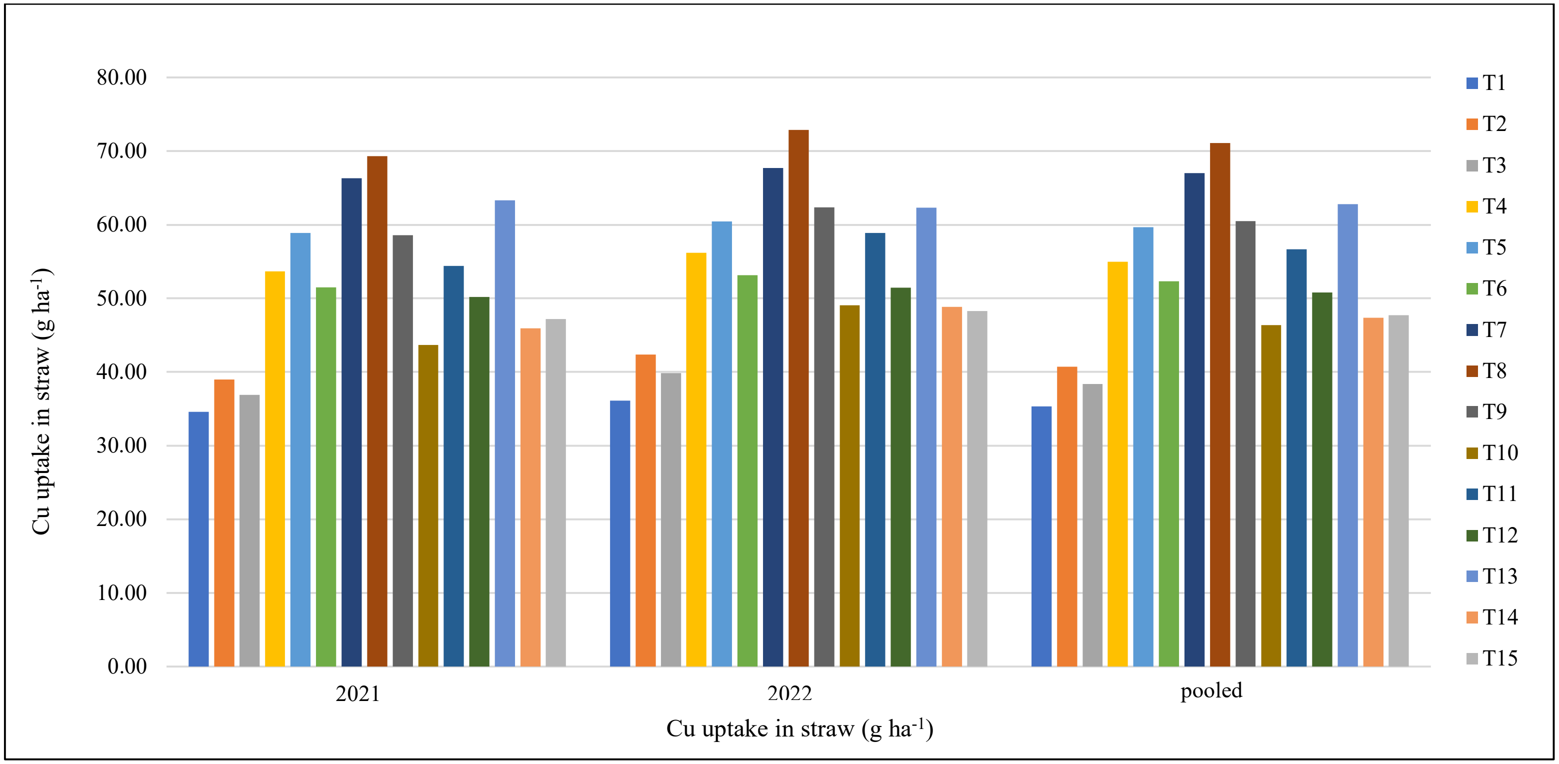


Fig 4.29: Effect of soil fertility management on Cu uptake in straw (g ha^{-1}) in direct-seeded rice

4.2.19 Total N uptake (kg ha^{-1})

Data pertaining to total nitrogen uptake in direct seeded rice under soil fertility management has been presented in table 4.17 and figuratively given in fig 4.30.

It was evident from the data that application of treatment T_8 recorded the highest total nitrogen uptake in both years of experimentation with 88.02 kg ha^{-1} and 92.49 kg ha^{-1} for the year 2021 and 2022 with pooled value of 90.26 kg ha^{-1}, while the lowest was recorded in control T_1 with 38.76 kg ha^{-1} and 40.31 kg ha^{-1} for the year 2021 and 2022 with pooled value of 39.53 kg ha^{-1} respectively. Treatment T_8 was significantly the highest among all the other treatments under study which was followed by treatment T_7 with 82.13 kg ha^{-1} and 85.33 kg ha^{-1} for the year 2021 and 2022 with pooled value 83.73 kg ha^{-1}, T_{13} with 77.47 kg ha^{-1} and 81.87 kg ha^{-1} for the year 2021 and 2022 with pooled value 79.67 kg ha^{-1} and T_5 with 74.52 kg ha^{-1} and 77.35 kg ha^{-1} for the year 2021 and 2022 with pooled value of 75.94 kg ha^{-1}, respectively. A further evaluation of the pooled data revealed that application of treatment T_8 significantly enhanced total N uptake to an extend of 166.16% over control, 7.79% over T_7, 13.29% over T_{13} and 18.85% over T_5 respectively.

The increased in total N uptake was directly related to the crop yields. High total N uptake can be associated to the treatment of soil with N, P, K, S, Zn and FYM application which increased nutrient availability and consequently improved the initial process of plant growth like cell division, number of root hairs, enabling the plant to develop healthy root system which helped in better absorption of nutrients and moisture from the soil (Subehia and Sepehya, 2012, Sahu and Chaubey, 2020). The results in this study are in conformity with Tiwari *et al.* (2020) who reported that highest total nitrogen uptake was recorded with full dose of NPK along with organic source as compared to other treatments which had lower levels of NPK or organic source alone.

4.2.20 Total P uptake (kg ha^{-1})

The results obtained on total phosphorus uptake in direct seeded rice under soil fertility management are summarized in table 4.17 and graphically displayed in fig 4.31.

It was apparent from the data that treatment T_8 obtained the maximum total phosphorus uptake with 18.89 kg ha^{-1} and 20.84 kg ha^{-1} in both years of experimentation and a pooled value 19.87 kg ha^{-1}, while the minimum was recorded in control T_1 with 6.11 kg ha^{-1} and 7.12 kg ha^{-1} for 2021 and 2022 with pooled value of 6.61 kg ha^{-1} respectively. This was followed by treatment T_7 with 16.70 kg ha^{-1} and 18.49 kg ha^{-}1 in 2021 and 2022 with a pooled value 17.60 kg ha^{-1} and T_{13} with 15.77 kg ha^{-1} and 17.49 kg ha^{-1} for the year 2021 and 2022 with pooled value16.63 kg ha^{-1} respectively. It was found that application of treatment T_8 enhanced the total P uptake by 179.07% over T_1, 12.86% over T_7 and 19.48% over T_{13}.

Increase in total P uptake with application of fertilizer in combination with FYM might be due to organic manures which modify the physical conditions of soil and helps in absorption and translocation of nutrients from soil, enhancing nutrient absorption and uptake. These findings are in conformity with Kumar *et al*. (2008), Shrivastava and Singh (2017) and Tiwari *et al*. (2020).

4.2.21 Total K uptake (kg ha^{-1})

Perusal data of total K uptake in direct seeded rice under soil fertility management has been presented in table 4.17 and figuratively depicted in fig 4.32.

It was evident from the data obtained that application of treatment T_8 recorded the maximum for total potassium uptake with 101.78 kg ha^{-1} and 107.60 kg ha^{-1} for the year 2021 and 2022 with a pooled value 104.69 kg ha^{-1}, while the minimum was observed in control treatment T_1 which recorded 50.55 kg ha^{-1} and 53.11 kg ha^{-1} for both the years 2021 and 2022 with pooled value 51.83 kg ha^{-1} respectively. Further evaluation of the recorded revealed that

Table 4.17: Effect of soil fertility management on total N, P, K uptake in direct seeded rice

Treatments	Total N uptake (kg ha^{-1})			Total P uptake (kg ha^{-1})			Total K uptake (kg ha^{-1})		
	2021	**2022**	**Pooled**	**2021**	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	38.76	40.31	39.53	6.11	7.12	6.61	50.55	53.11	51.83
T_2- 100% NPK	56.15	58.56	57.36	10.77	11.61	11.19	65.04	69.67	67.35
T_3- 50% NPK	49.78	53.52	51.65	9.71	10.79	10.25	61.69	65.87	63.78
T_4- SSNM (109:30:46 NPK)	68.78	72.02	70.40	13.50	14.50	14.00	83.10	88.10	85.60
T_5- 100% NPK + Zn	74.52	77.35	75.94	14.92	15.69	15.30	89.66	94.46	92.06
T_6- 100% NPK + S	65.02	68.48	66.75	11.86	13.24	12.55	76.10	80.83	78.46
T_7- 100% NPK +Zn + S	82.13	85.33	83.73	16.70	18.49	17.60	95.35	98.98	97.17
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	88.02	92.49	90.26	18.89	20.84	19.87	101.78	107.60	104.69
T_9- 100% NPK + Liming @LR	70.85	75.25	73.05	14.24	15.64	14.94	84.06	91.25	87.66
T_{10}- 50% NPK + Azospirillum	56.57	62.12	59.35	10.36	11.81	11.09	66.77	76.50	71.63
T_{11}- 50% NPK + 50% N-FYM	66.32	70.96	68.64	12.84	14.21	13.53	78.89	85.84	82.37
T_{12}- 50% NPK + 50% N- VC	61.80	65.93	63.87	11.50	12.75	12.12	73.19	77.03	75.11
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	77.47	81.87	79.67	15.77	17.49	16.63	91.72	96.62	94.17
T_{14}- FYM @ 10 t ha^{-1}	60.33	63.79	62.06	11.02	12.40	11.71	68.78	74.62	71.70
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	58.64	61.94	60.29	11.27	12.37	11.82	69.34	73.25	71.30
SEm±	0.81	0.98	0.64	0.25	0.34	0.21	0.73	0.87	0.57
CD(P=0.05)	2.36	2.83	1.80	0.72	1.00	0.60	2.11	2.51	1.60

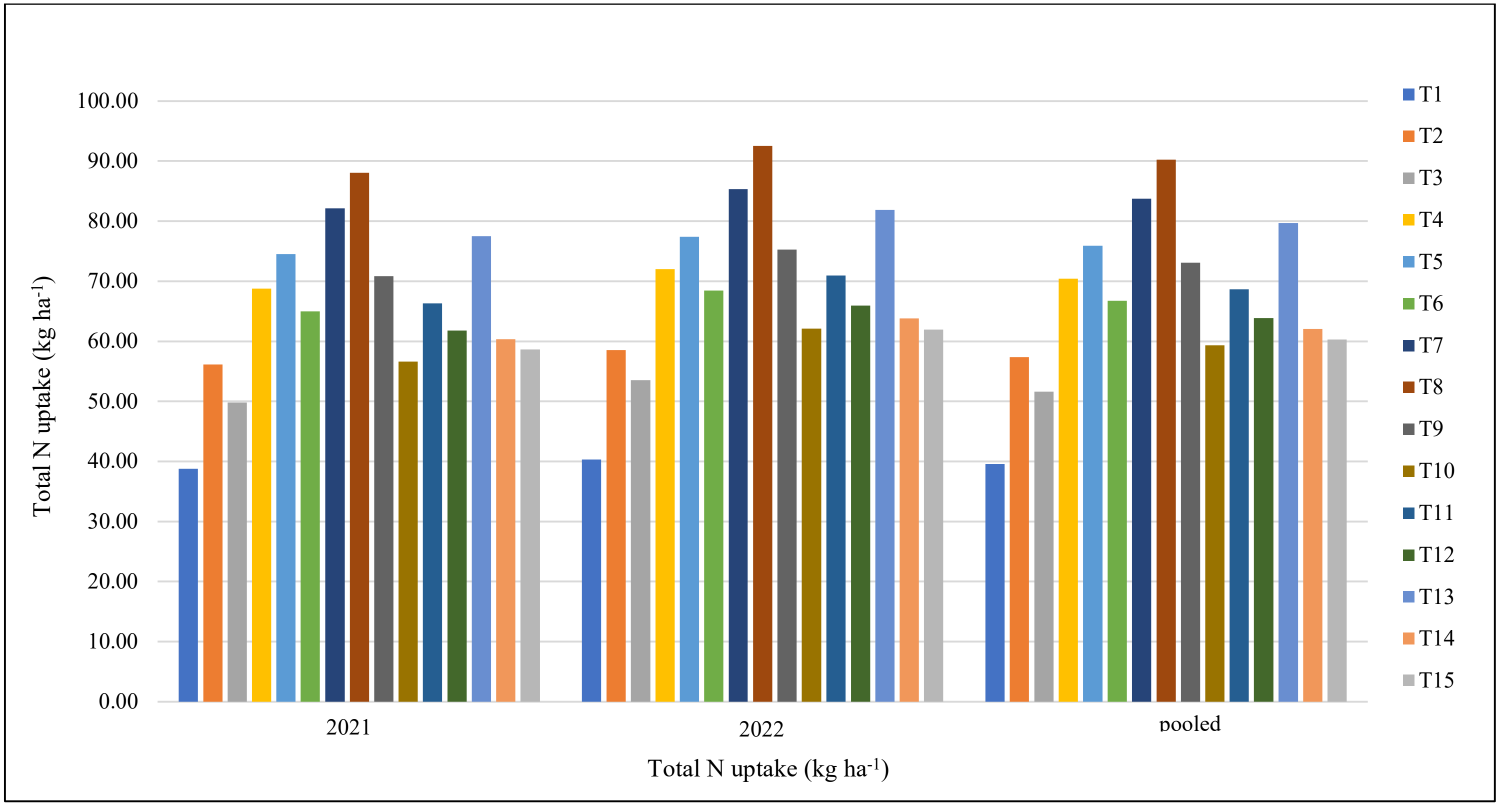


Fig 4.30: Effect of soil fertility management on total N uptake (kg ha^{-1}) in direct-seeded rice

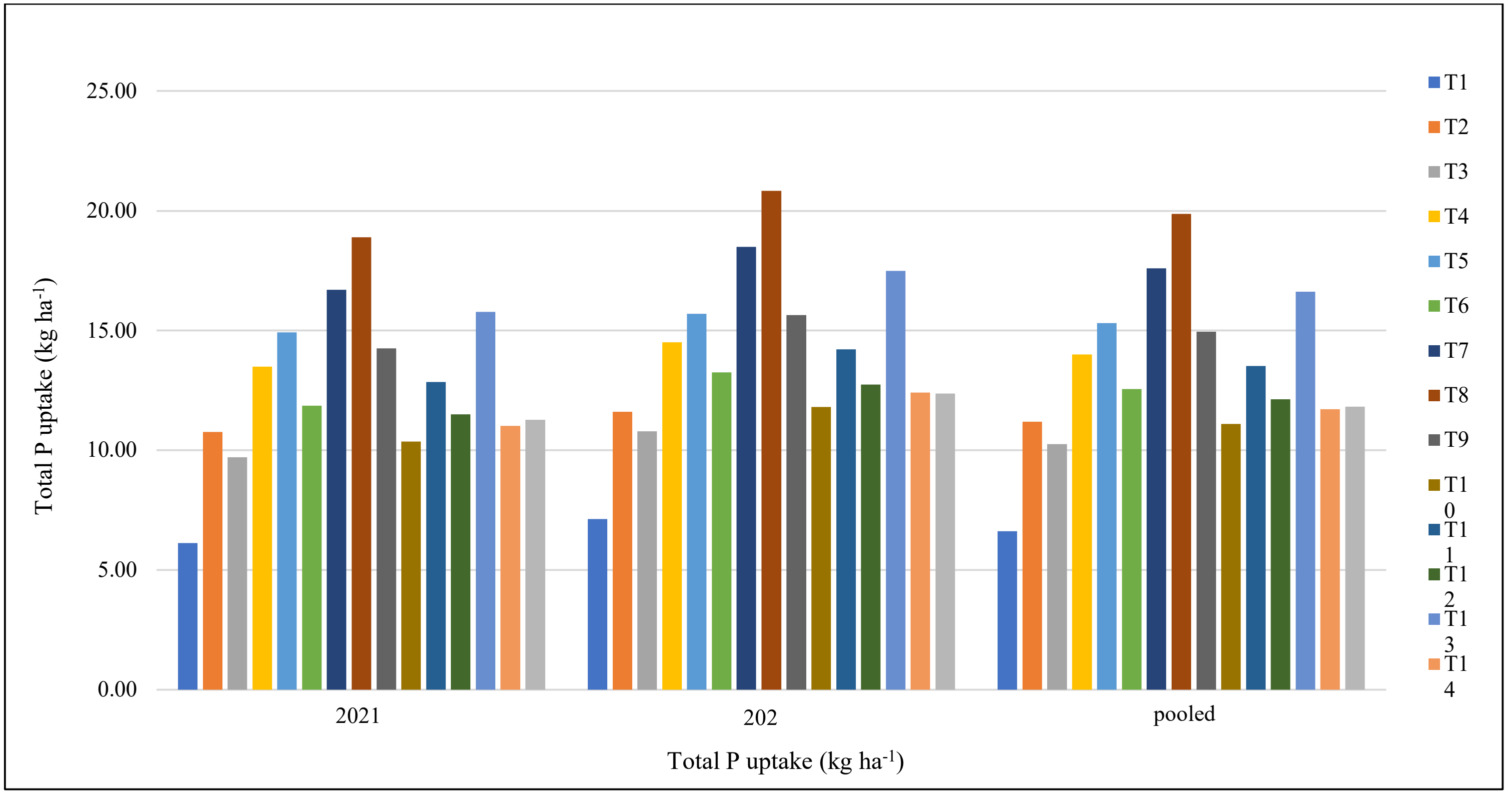


Fig 4.31: Effect of soil fertility management on total P uptake (kg ha^{-1}) in direct-seeded rice

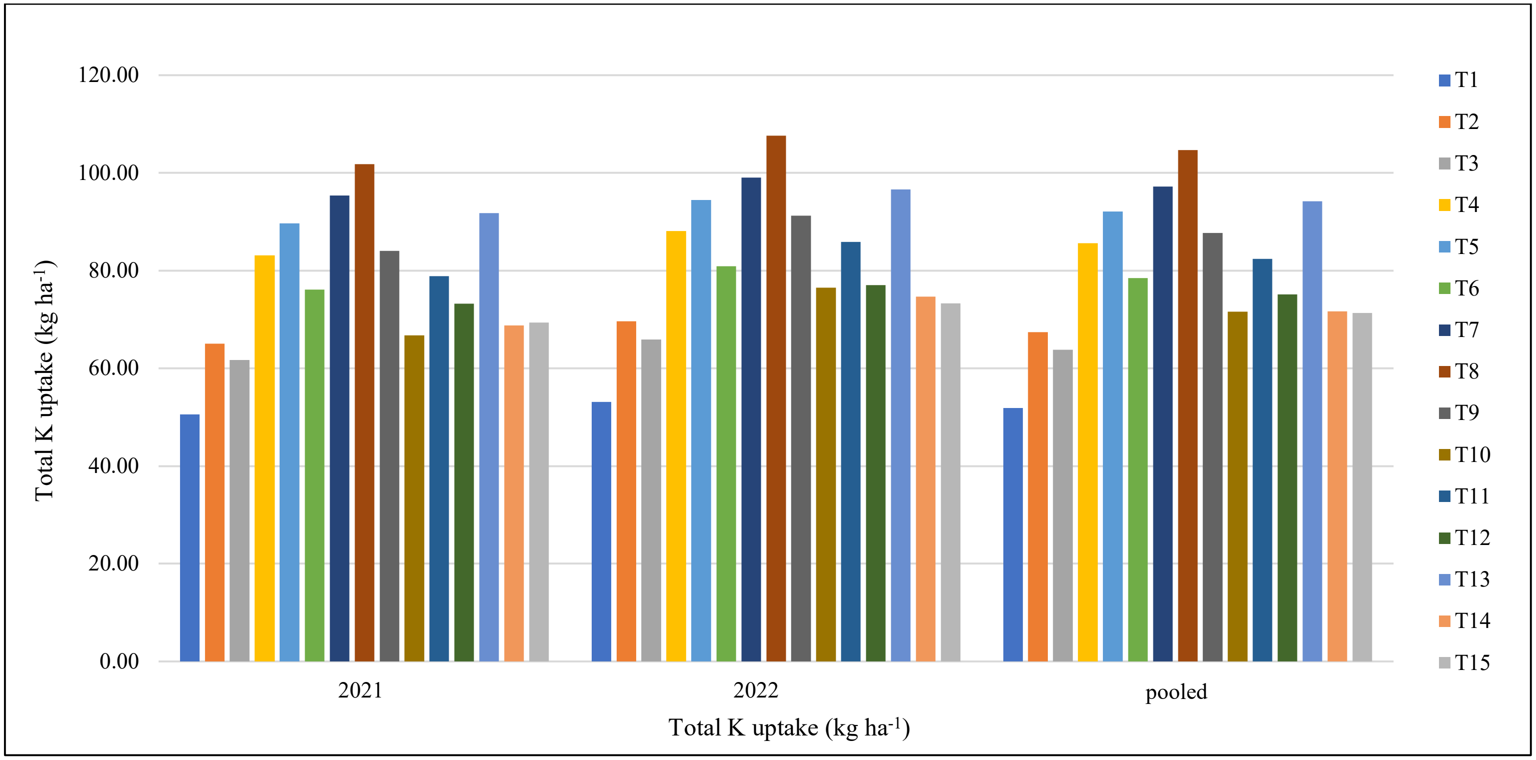


Fig 4.32: Effect of soil fertility management on total K uptake (kg ha^{-1}) in direct-seeded rice

treatment T_8 was significantly the highest which was followed by T_7 with 95.35 kg ha^{-1} and 98.98 kg ha^{-1} for 2021 and 202 with pooled value 97.17 kg ha^{-1} and T_{13} with 91.72 kg ha^{-1} and 96.62 kg ha^{-1} for 2021 and 2022 with pooled value 94.17 kg ha^{-1} respectively. It was also found that treatment T_{13} was at par with T_5 with 89.66 kg ha^{-1} and 94.46 kg ha^{-1} for both the years of experimentation. Application of treatment T_8 was proved to have increased the total potassium uptake for both years and from the pooled value it recorded an increase of about 101.98% over control T_1, 7.76% over T_7 and 11.17% over T_{13}, respectively.

The higher uptake maybe be due to the balanced dose of fertilizer which made the nutrients available in right proportions as compared to control which had no nutrient application. The results are in conformity with Mousami *et al*. (2020) who similarly reported higher total K uptake in rice due to balanced recommended doses of fertilizers N-P-K-S-Zn. Higher assimilation of nutrients in plant tissue as well as biomass production attributed to increase nutrients uptake. The fertilizers along with FYM additionally supplies N, P, K to plant foliage leads to quickly supply of nutrients to plant. Optimum and continuous availability of nutrients to plant increase the uptake as well as assimilation in plant tissue, leads to increase nutrients content of plant (Kumar *et al*., 2022).

4.2.22 Total S uptake (kg ha^{-1})

The data pertaining to total sulphur uptake in direct seeded rice crop under soil fertility management has been summarized in table 4.18 and figuratively portrayed in fig 4.33.

The results indicated that application of treatment T_8 increased the total sulphur uptake of the rice crop for both years of experimentation significantly over control as well as with other treatments in comparison respectively. The maximum total S uptake was observed with T_8 which recorded 36.86 kg ha^{-1} and 39.64 kg ha^{-1} for 2021 and 2022 with pooled value of 38.25 kg ha^{-1} while the minimum was recorded in control T_1 with 12.28 kg ha^{-1} and 13.44 kg ha^{-1} for 2021 and 2022 with pooled value 12.86 kg ha^{-1} respectively. It was observed that treatments which had sulphur sources recorded a higher total sulphur uptake in rice crop as compared to other treatments as follows $T_8>T_7>T_5>T_{13}>T_4>T_9>T_6$ among which T_{13} and T_4 had an absence of sulphur but also recorded a comparatively higher total sulphur uptake which could be probably due to the sufficient available nutrients owing to the higher NPK rate of application. Further critical evaluation of the data reported that application of treatment T_8 increased total sulphur uptake to an extend of 197.43% over control T_1, 34.25% over T_{13} and 36.90% over T_4, respectively.

Nitrogen, phosphorus and potassium uptake in crop increased significantly with the application of sulphur and zinc (Dixit *et al*., 2018). Increase in sulphur and zinc levels significantly increase nutrient uptake by rice crop (Niraj *et al*., 2014). Sulphur fertilizer increased the sulphur content and uptake in crop (Ali *et al*., 2004).

4.2.23 Total Ca uptake (kg ha^{-1})

Perusal data of total calcium uptake in direct seeded rice under soil fertility management has been displayed in table 4.18 and graphically depicted in fig 4.34.

It was apparent from the data obtained that treatment T_8 recorded significantly the highest total calcium uptake among all the other treatments whereas the lowest was recorded with control T_1 which had no any source of nutrient application. The values varied from 68.16 kg ha^{-1} and 72.48 kg ha^{-1} to 42.13 kg ha^{-1} and 44.77 kg ha^{-1} for both the years of experimentation 2021 and 2022, with pooled value also varying from 70.32 kg ha^{-1} to 43.45 kg ha^{-1}, respectively. Critical evaluation of the treatments also revealed that treatment T_8 performed better than those lime treated plots specifically T_9 which recorded 59.94 kg ha^{-1} and 64.30 kg ha^{-1} for both the year 2021 and 2022 and T_{15} with 51.78 kg ha^{-1} and 53.93 kg ha^{-1} for 2021 and 2022 respectively. From the pooled value, it reported that treatment T_8 documented an increase of about 61.84% over

Table 4.18. Effect of soil fertility management on total S and Ca uptake in direct seeded rice

Treatments	Total S uptake (kg ha^{-1})			Total Ca uptake (kg ha^{-1})		
	2021	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	12.28	13.44	12.86	42.13	44.77	43.45
T_2- 100% NPK	18.40	19.31	18.85	51.62	56.06	53.84
T_3- 50% NPK	19.81	21.01	20.41	49.40	54.09	51.75
T_4- SSNM (109:30:46 NPK)	26.96	28.93	27.94	58.72	63.13	60.92
T_5- 100% NPK + Zn	29.91	30.88	30.39	62.16	65.60	63.88
T_6- 100% NPK + S	26.89	28.86	27.87	55.82	59.85	57.83
T_7- 100% NPK +Zn + S	33.57	36.16	34.87	64.85	67.71	66.28
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	36.86	39.64	38.25	68.16	72.48	70.32
T_9- 100% NPK + Liming @LR	26.73	29.14	27.94	59.94	64.30	62.12
T_{10}- 50% NPK + Azospirillum	23.96	26.46	25.21	53.38	61.15	57.27
T_{11}- 50% NPK + 50% N-FYM	25.18	27.85	26.52	57.71	62.52	60.11
T_{12}- 50% NPK + 50% N- VC	23.94	26.15	25.05	56.52	58.65	57.59
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	27.43	29.56	28.49	63.76	66.92	65.34
T_{14}- FYM @ 10 t ha^{-1}	21.12	22.98	22.05	53.10	57.55	55.32
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	20.49	21.47	20.98	51.78	53.93	52.86
SEm±	0.65	0.67	0.47	1.11	1.06	0.77
CD(p=0.05)	1.89	1.95	1.33	3.22	3.08	2.18

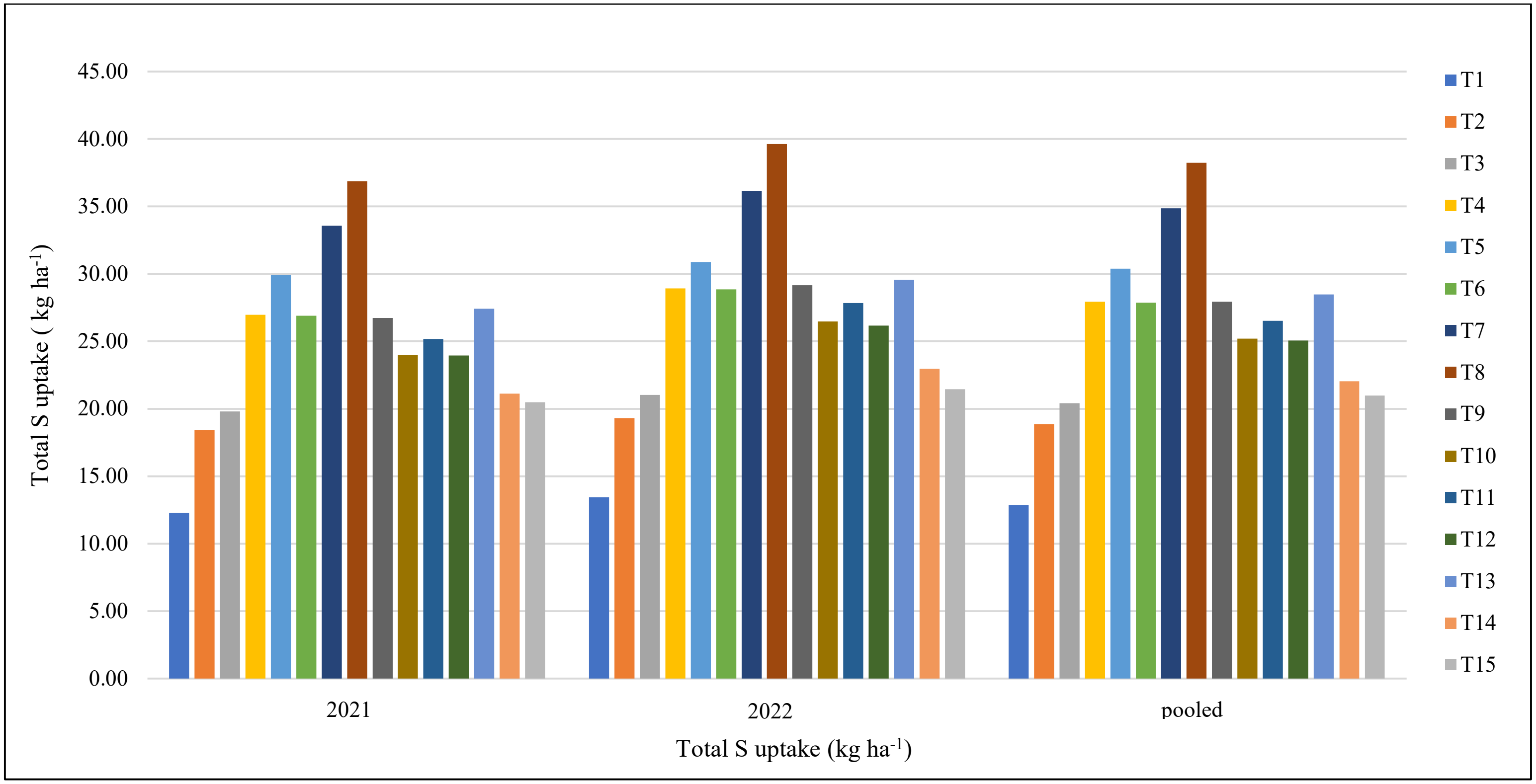


Fig 4.33: Effect of soil fertility management on total S uptake (kg ha^{-1}) in direct-seeded rice

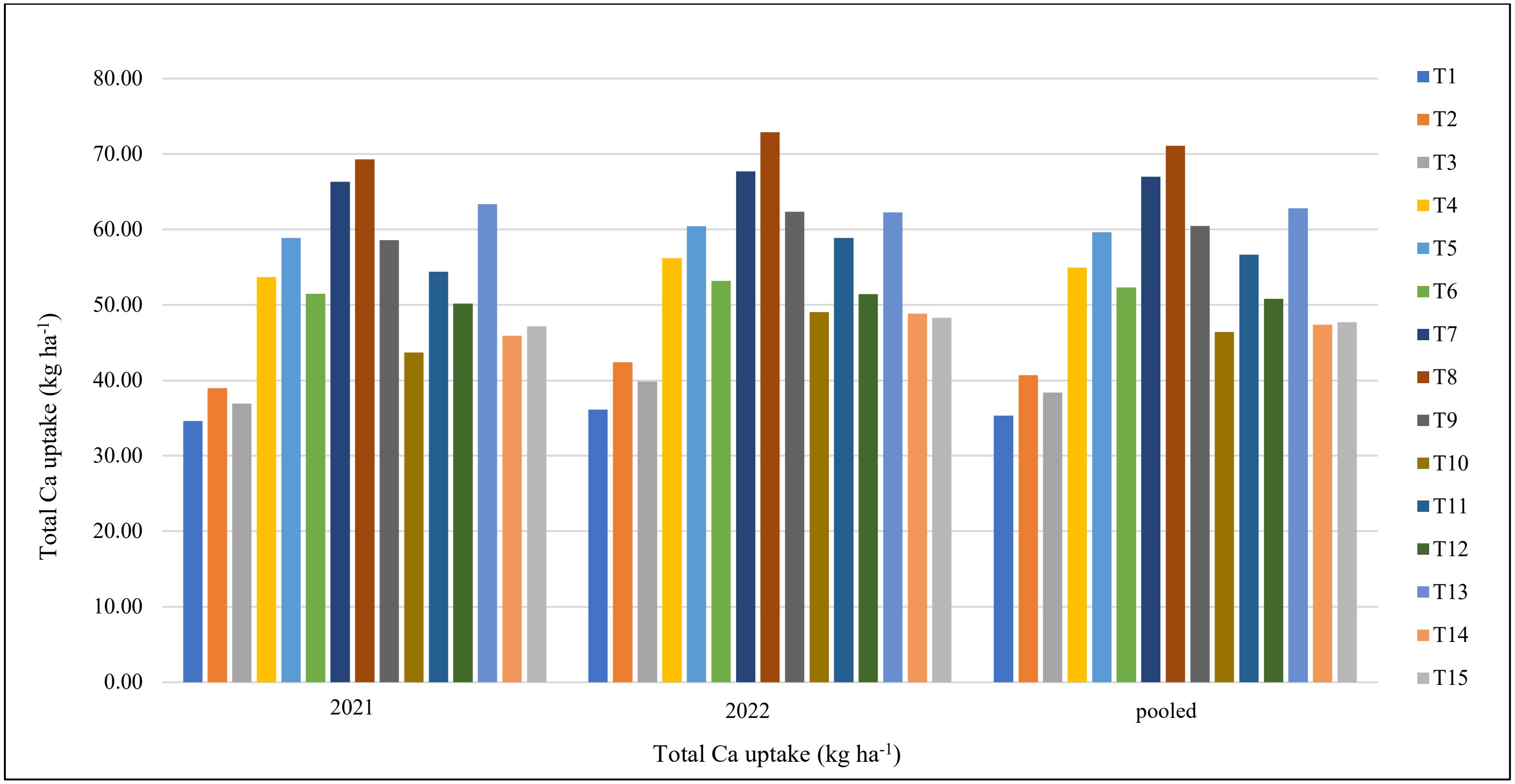


Fig 4.34: Effect of soil fertility management on total S uptake (kg ha^{-1}) in direct-seeded rice

control T_1, 6.09% over T_7, 13.20% over T_9, 7.63 % over T_{13}, and 33.03% over T_{15} for total calcium uptake in direct seeded rice.

The nutrient uptake by the whole plant was significantly enhanced with the above treatments. Geetha Sireesha *et al*. (2017) reported that the higher nutrient uptake by the crop was mainly attributable to the higher dry matter accumulation since FYM supply both major and minor nutrients along with organic acids which provides good soil physical condition for overall plant growth and development. The increased uptake of nutrient positively augmented photosynthesis and yield of the rice crop.

4.2.24 Total Zn uptake (g ha^{-1})

The results for total zinc uptake in direct seeded rice has been presented in table 4.19 and figuratively displayed in fig 4.35.

According to the results obtained it was comprehensible that application of treatment T_8 which recorded a value of 416.58 g ha^{-1} and 436.73 g ha^{-1} for the year 2021 and 2022 with pooled value 426.66 g ha^{-1} significantly gave the highest total zinc uptake in rice while control T_1 with 230.83 g ha^{-1}and 238.10 g ha^{-1} for both years 2021 and 2022 with the pooled value of 234.46 g ha^{-1} recorded the lowest among all the other treatments respectively. With further critical evaluation it was found that zinc treated plots recorded higher total zinc uptake as compared to non-treated plots and control, which followed an order of $T_8 > T_7 > T_5 > T_{13} > T_9 > T_4$. It was also observed that treatment T_8 was at par with T_7 (395.67 g ha^{-1}) for the year 2021, while T_7 was at par with T_5 (373.85 g ha^{-1} and 386.10 g ha^{-1}) and T_{13} (371.20 g ha^{-1} and 386.16 g ha^{-1}) respectively for both the years of experimentation 2021 and 2022. Comparison among other treatments also revealed that treatment T_5 was at par with T_4 (350.65 g ha^{-1} and 363.67 g ha^{-1}) and T_9 (352.91 g ha^{-1} and 372.50 g ha^{-1}) for both the years 2021 and 2022 respectively. Application of treatment T_8 increased total zinc uptake in rice crop to an extend of 81.95% over control T_1, 6.08% over T_7, 12.28% over T_5 and 12.67% over T_{13} respectively.

Uptake of zinc was increased with increasing rate of fertilizer as 100% NPK performed better than 50% NPK in comparison. Mousomi *et al*. (2020) noticed that having recommended package of fertilizer in soil showed highest value of zinc uptake as compared to control. Zinc content in grains increased markedly by the application of zinc as compared to NPK alone. Similar results were recorded by Sudha *et al*. (2015) and Khan *et al*. (2007). The findings are in accordance with the results of Srivastava and Singh (2017) who reported that application of varying levels of NPK increased the plant zinc uptake of rice crop among which 100% NPK along with FYM performed better among all the other levels.

4.2.25 Total Fe uptake (g ha^{-1})

Data regarding total iron uptake in direct seeded rice under soil fertility management are depicted in table 4.19 and figuratively displayed in fig 4.36.

It was apparent from the data obtained that application of treatment T_8 recorded the highest total iron uptake with 874.99 g ha^{-1} and 915.29 g ha^{-1} for the years 2021 and 2022 and pooled value of 895.14 g ha^{-1} while control T_1 recorded the lowest total iron uptake with 523.84 g ha^{-1} and 539.77 g ha^{-1} for both years 2021 and 2022 and with a pooled value 531.81 g ha^{-1} among all the other treatments respectively. The treatment T_8 recorded significantly the highest which was followed by T_7 (830.56 g ha^{-1} and 855.70 g ha^{-1}) and T_{13} (801.30 g ha^{-1} and 833.13 g ha^{-1}) during both the years of experimentation 2021 and 2022 respectively, meanwhile T_7 was found to be at par with T_{13}. Further examination among the treatments revealed that T_8 recorded an increase of about 68.31% over control, 6.16% over T_7 and 9.53% over T_{13} respectively.

Iron transport from root to shoot and grain is essential for normal plant growth. The increase in total iron uptake by rice crop may be attributed to higher grain and straw production. The conjoint application of organic manures along with recommended dose of fertilizer increase the micronutrients uptake in comparison to control treatment (Singh *et al*., 2018). The findings are in concordance with the findings of Swarup and Yaduvenshi, (2004).

4.2.26 Total Mn uptake (g ha^{-1})

Data regarding total manganese uptake in direct seeded rice under soil fertility management are shown in table 4.19 and graphically arranged in fig 4.37.

From the data obtained through the experiment, it was observed that application of treatment T_8 recorded the highest total manganese uptake with 647.81 g ha^{-1} and 677.41 g ha^{-1} for both years 2021 and 2022 with a pooled value of 662.61 g ha^{-1} while control T_1 recorded the lowest with 363.00 g ha^{-1} and 375.34 g ha^{-1} for both 2021 and 2022 with pooled value of 369.17 g ha^{-1} among all the other treatments respectively. The treatment T_8 recorded significantly the highest followed by T_7 with 608.02 g ha^{-1} and 627.38 g ha^{-1} for 2021 and 2022 and T_{13} with 586.36 g ha^{-1} and 610.35 g ha^{-1} for 2021 and 2022 respectively, meanwhile treatment T_7 was found to be at par with T_{13}. Further examination among the treatments revealed that T_8 recorded an increase of about 79.48% over control, 7.27% over T_7 and 10.73% over T_{13} respectively.

Increased in total Mn uptake in this study can also be attributed to the increase yield in grain and straw of the crop. Similar findings were also reported by Rani and Sukumari, (2013). Integrated nutrient management is the best approach to supply adequate and balanced nutrients and increase crop productivity. Mithun *et al*. (2007) and Srinivasan and Angayarkanni, (2008) reported that uptake of nutrients was improved by the application of integrated use of organic and inorganic fertilizer compared to RDF.

4.2.27 Total Cu uptake (g ha^{-1})

The results pertaining to total copper uptake in direct seeded rice under soil fertility management are presented in table 4.19 and figuratively shown in fig 4.38.

Perusal data of total copper uptake revealed that application of treatment T_8 recorded the maximum with 106.41 g ha^{-1} for 2021 and 111.83 g ha^{-1} for 2022 and with a pooled value of 109.12 g ha^{-1}, while the minimum was recorded in the control treatment T_1 with 45.70 g ha^{-1} for 2021 and 47.63 g ha^{-1} for 2022 with pooled value of 46.66 g ha^{-1} respectively. Further evaluation of the treatments revealed that T_8 was at par with T_7 (100.55 g ha^{-1} and 103.36 g ha^{-1}), T_9 (87.87 g ha^{-1} and 92.70 g ha^{-1}), T_{13} (93.56 g ha^{-1} and 94.51 g ha^{-1}) for both the years 2021 and 2022 while at par with T_5 (87.48 g ha^{-1}) for the year 2021 only. Treatment T_8 recorded an increase in total copper uptake of about 133.86% over control T_1, 7.03% over T_7, 16.04% over T_{13}, 20.86% over T_9 and 22.99% over T_5 respectively.

Cui *et al*. (2022) observed that nitrogen supply is beneficial for more distribution of Cu to the shoot, which may promote the growth of rice plant. The results from this study also saw a steady increase in total copper uptake in the treatments which received ample nutrients specially nitrogen through inorganic fertilizer as well as from the organic source FYM. The increasing copper uptake in the plant can also be due to the increase yield of grain and straw as total uptake by the crop are related to yields.

Table 4.19: Effect of soil fertility management on total Zn, Fe, Mn and Cu uptake in direct seeded rice

Treatments	Total Zn uptake (g ha^{-1})			Total Fe uptake (g ha^{-1})			Total Mn uptake (g ha^{-1})			Total Cu uptake (g ha^{-1})		
	2021	**2022**	**pooled**	**2021**	**2022**	**pooled**	**2021**	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	230.83	238.10	234.46	523.84	539.77	531.81	363.00	375.34	369.17	45.70	47.63	46.66
T_2- 100% NPK	296.85	309.51	303.18	650.87	677.38	664.12	453.69	472.39	463.04	56.95	60.48	58.72
T_3- 50% NPK	281.30	297.00	289.15	618.15	653.98	636.06	426.15	455.39	440.77	53.36	56.74	55.05
T_4- SSNM (109:30:46 NPK)	350.65	363.67	357.16	746.41	774.68	760.54	535.01	555.23	545.12	80.96	84.22	82.59
T_5- 100% NPK + Zn	373.85	386.10	379.98	780.61	805.57	793.09	568.87	587.03	577.95	87.48	89.96	88.72
T_6- 100% NPK + S	337.40	351.18	344.29	711.00	739.91	725.45	501.74	521.81	511.78	75.88	78.36	77.12
T_7- 100% NPK +Zn + S	395.67	408.71	402.19	830.56	855.70	843.13	608.02	627.38	617.70	100.55	103.36	101.95
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	416.58	436.73	426.66	874.99	915.29	895.14	647.81	677.41	662.61	106.41	111.83	109.12
T_9- 100% NPK + Liming @LR	352.91	372.50	362.70	754.50	796.89	775.70	549.54	578.95	564.24	87.87	92.70	90.28
T_{10}- 50% NPK + Azospirilllum	292.53	324.61	308.57	652.36	725.36	688.86	457.50	507.74	482.62	61.75	67.72	64.74
T_{11}- 50% NPK + 50% N-FYM	337.20	357.87	347.54	719.16	761.42	740.29	523.38	555.31	539.35	79.51	85.06	82.28
T_{12}- 50% NPK + 50% N- VC	320.83	332.66	326.74	688.80	713.26	701.03	489.72	510.93	500.33	72.82	75.47	74.15
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	371.20	386.16	378.68	801.30	833.13	817.22	586.36	610.35	598.35	93.56	94.51	94.03
T_{14}- FYM @ 10 t ha^{-1}	303.38	319.40	311.39	672.68	708.38	690.53	474.72	499.71	487.22	67.58	71.78	69.68
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	291.19	301.89	296.54	644.98	668.07	656.52	460.76	478.15	469.46	68.43	71.09	69.76
SEm±	9.36	9.00	6.49	10.32	11.22	7.63	12.57	13.97	9.39	7.17	6.76	4.93
CD(p=0.05)	27.12	26.07	18.40	29.91	32.51	21.60	36.40	40.46	26.61	20.77	19.58	13.96

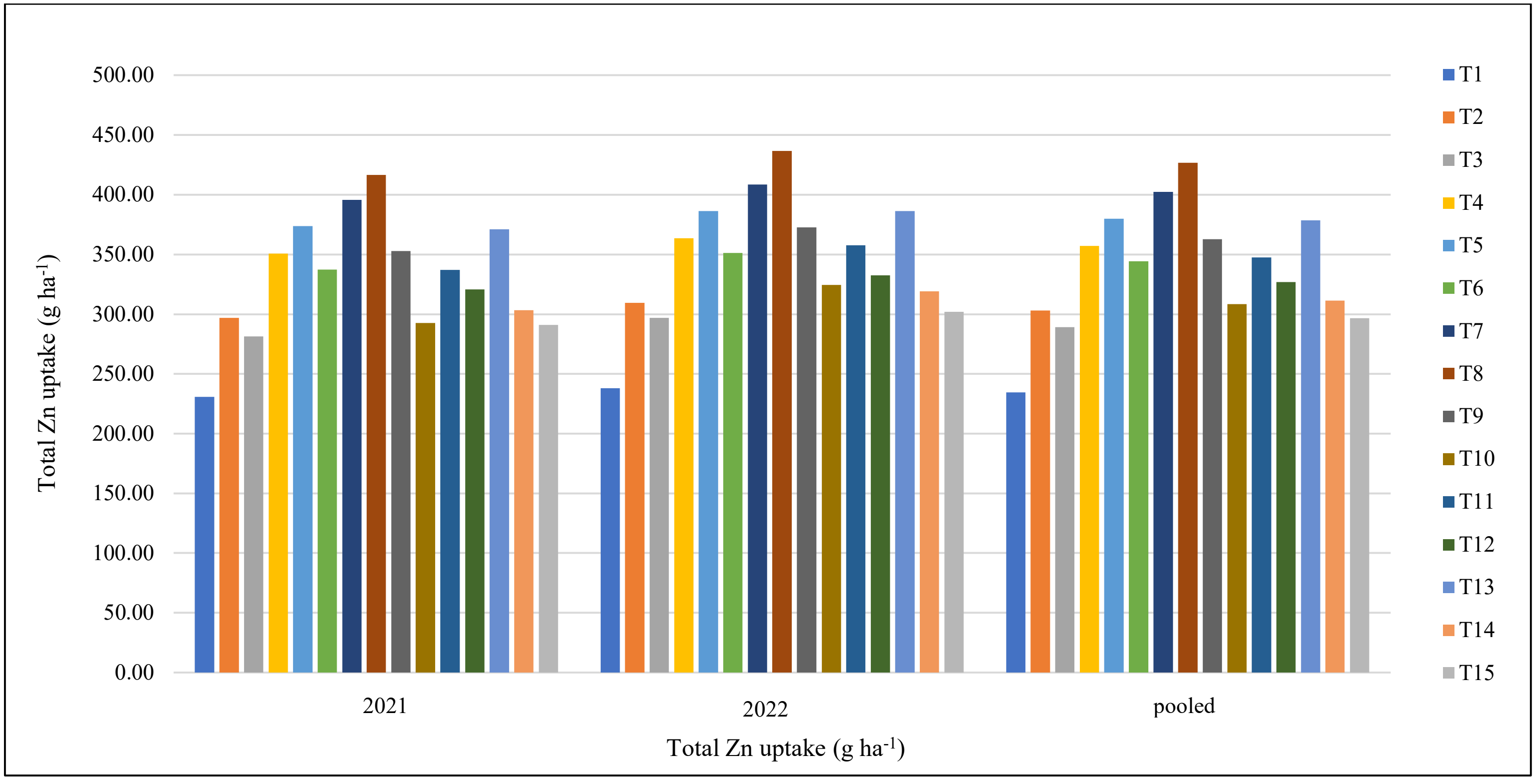


Fig 4.35: Effect of soil fertility management on total Zn uptake (g ha^{-1}) in direct-seeded rice

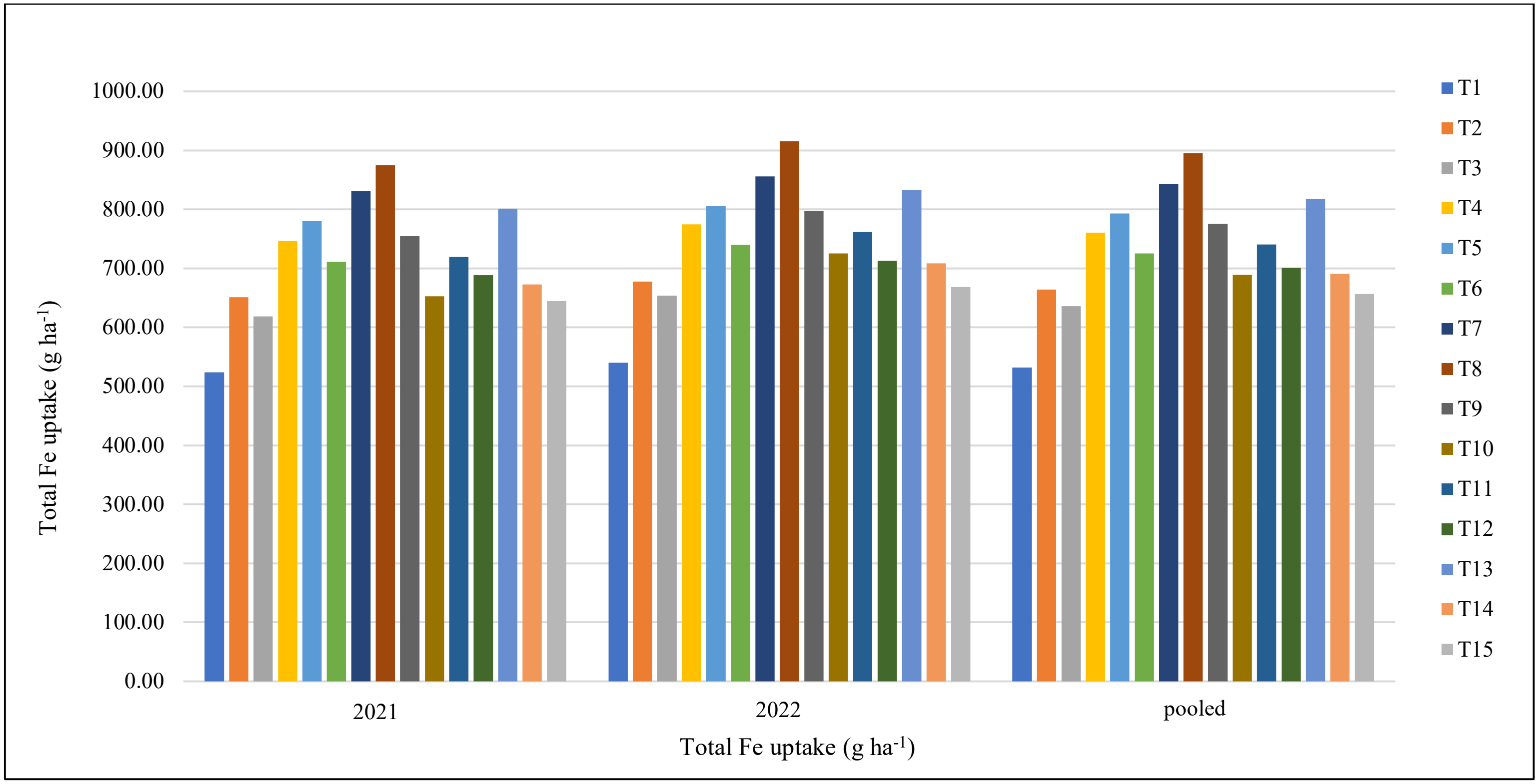


Fig 4.36: Effect of soil fertility management on total Fe uptake (g ha^{-1}) in direct-seeded rice

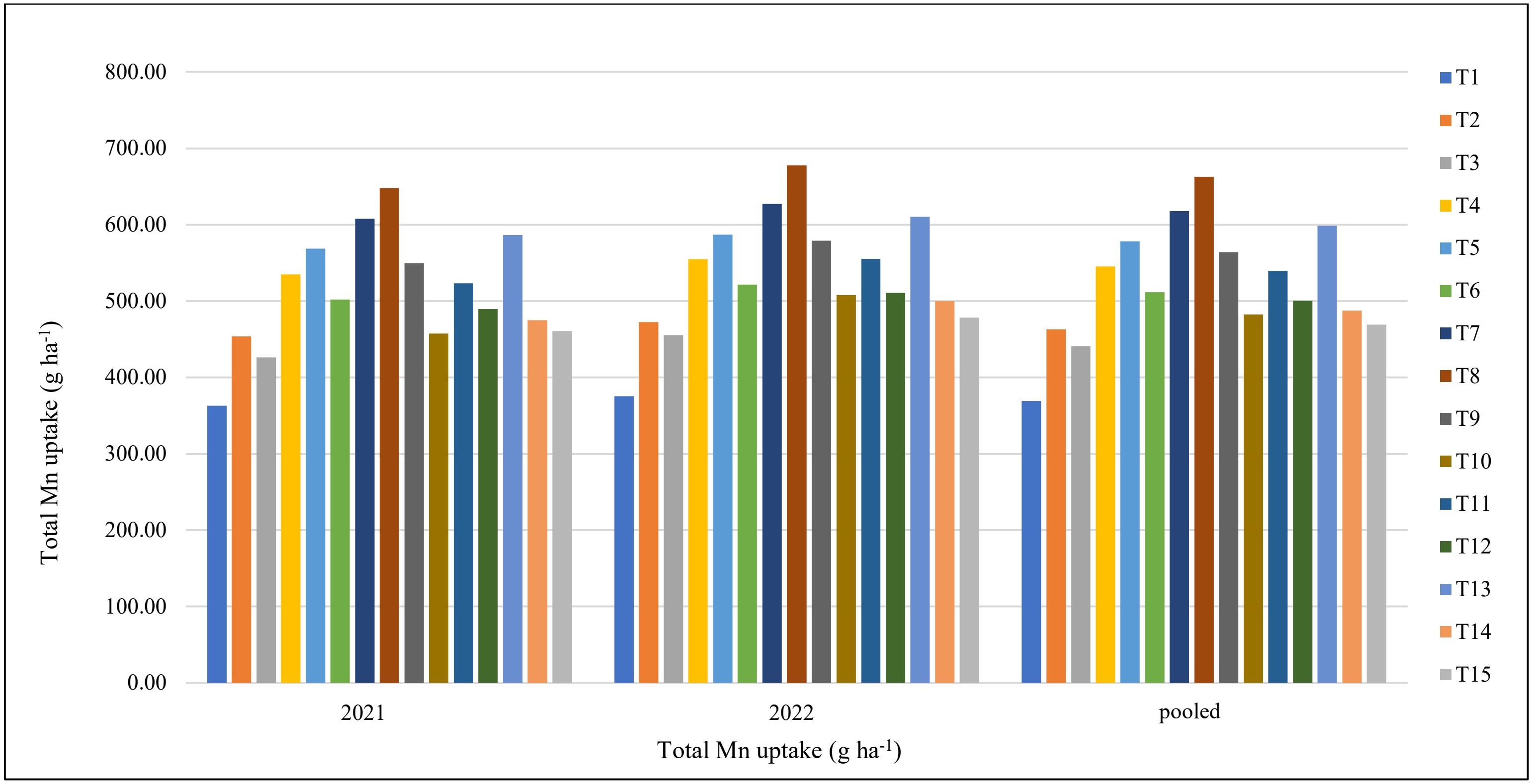


Fig 4.37: Effect of soil fertility management on total Mn uptake (g ha^{-1}) in direct-seeded rice

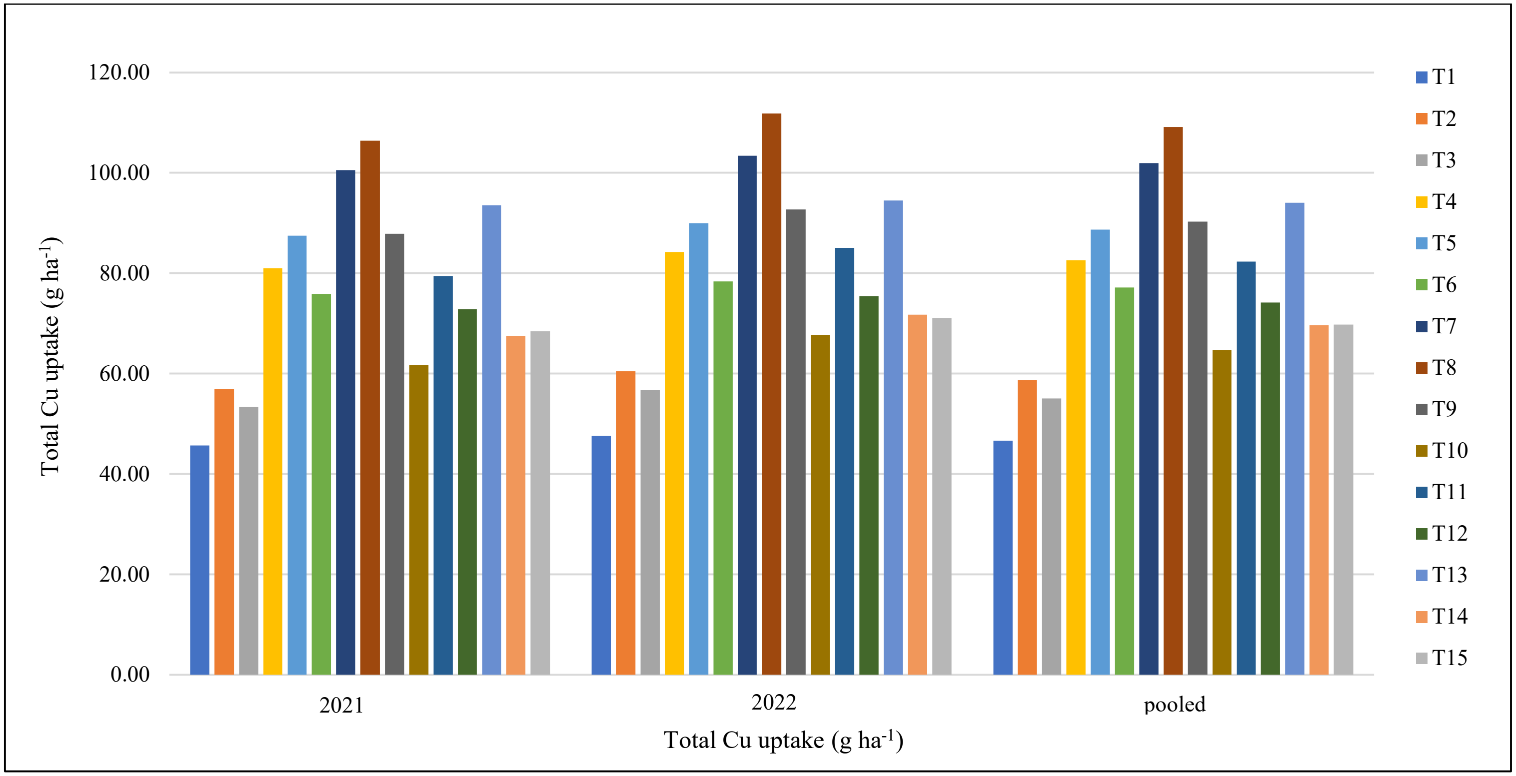


Fig 4.38: Effect of soil fertility management on total Cu uptake (g ha^{-1}) in direct-seeded rice

4.3 Effect of soil fertility management on soil properties in direct seeded rice.

The various treatments incorporated in this field experiment after the completion of two years was observed to determine the changes in the properties of soil. The results obtained for both the years revealed that the chemical, physical and biological properties of post-harvest soil were positively enhanced where the inorganic fertilizers which readily provided the available nutrients for the plants simultaneously the organic sources with its slow decomposing nature later supported the overall soil environment by maintaining a sufficient nutrient pool.

4.3.1 Soil pH

The perusal data on pH as affected by the various treatments under soil fertility management in direct seeded rice revealed that application of inorganic and organic sources of nutrients through different treatments did not show a wide variation in soil pH effect during both the years of experimentation which has been presented in table 4.20 and displayed in fig 4.39. However, lime treatments were effective in raising pH to a desirable value as pooled value disclosed that pH varied from 4.50 to 5.96. The lowest was recorded with control T_1 (4.43 and 4.57) while the highest as reported from T_{15} with 5.95 for the year 2021 and 5.97 for 2022 respectively. Treatments treated with lime displayed a higher pH as compared to those treatments which had no nutrient source or inorganic fertilizer alone. Besides lime which is known for raising pH for acidic soils, the slight raise in soil pH in other treatments may be attributed due to the presence of organic sources like FYM, vermicompost and Azospirillum which decreases the activity of exchangeable Al^{3+} ions in soil solution due to chelation effect of organic molecules and in addition promotes the release of basic cations like K^+, Ca^{2+}, Mg^{2+} and Na^+ in soil (Patra *et al*., 2020). Integrated nutrient application also proved to have slightly raised the soil pH as compared to control in this study. Similar findings were also reported by Goswami and Pandey (2018).

4.3.2 EC (dSm^{-1})

The results on electrical conductivity of soil due to the various treatments under study are presented in table 4.20. Perusal data revealed that soil electrical conductivity was proved to be non-significant as the different treatments could not show any statistical difference. The value varied from 0.02 to 0.04 (dSm^{-1}) for both years of experimentation 2021 and 2022.

4.3.3 Bulk density (g cm^{-3})

The data pertaining to bulk density of the soil under soil fertility management in direct seeded rice has been displayed in table 4.20. From the results obtained it revealed that bulk density of the soil varied between 1.41 g cm^{-3} to 1.45 g cm^{-3} where the highest was recorded with control T_1 with 1.45 g cm^{-3} and 1.45 g cm^{-3} and lowest was in treatment T_{15} with 1.41 g cm^{-3} and 1.41 g cm^{-3} for both years of experimentation 2021 and 2022, respectively. The study also showed that the bulk density showed a decreasing trend with the treatments which had organic sources as compared to treatments which had no nutrient application or inorganic fertilizers alone. The decrease in bulk density of the soil might be due to increase in humic substances of soil which resulted in increased porosity and water holding capacity of soil (Babulkar *et al*., 2000). The bulk density of soil has been lowered with the incorporation of FYM organic manure over no manure as a well aggregated soil has a lower bulk density in comparison with dispersed and poorly aggregated soil. Addition of organic manure resulted in considerable increase in polysaccharides and microbial gum synthesis in the soil. The microbial decomposition product being resistant to further decomposition acts as binding material which might help in soil aggregation resulting in lowering of the bulk density of the soil. This are in conformity with the findings of Aziz *et al*. (2019). The results for bulk density of soil in this study failed to show any significant difference among the treatments.

Table 4.20: Effect of soil fertility management on pH, EC and bulk density in direct seeded rice

Treatments	pH			EC (dSm^{-1})			Bulk density ($g\ cm^{-3}$)		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	4.43	4.57	4.50	0.03	0.03	0.03	1.45	1.45	1.45
T_2- 100% NPK	4.70	4.77	4.73	0.04	0.04	0.04	1.42	1.42	1.42
T_3- 50% NPK	4.73	4.79	4.76	0.03	0.03	0.03	1.42	1.42	1.42
T_4- SSNM (109:30:46 NPK)	4.70	4.76	4.73	0.03	0.03	0.03	1.43	1.43	1.43
T_5- 100% NPK + Zn	4.65	4.67	4.66	0.04	0.04	0.04	1.42	1.43	1.43
T_6- 100% NPK + S	4.72	4.74	4.73	0.04	0.04	0.04	1.42	1.42	1.42
T_7- 100% NPK +Zn + S	4.84	4.86	4.85	0.03	0.04	0.03	1.42	1.42	1.42
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	4.78	4.72	4.75	0.04	0.04	0.04	1.42	1.42	1.42
T_9- 100% NPK + Liming @LR	5.83	5.85	5.84	0.04	0.03	0.04	1.43	1.43	1.43
T_{10}- 50% NPK + Azospirillum	4.81	4.85	4.83	0.02	0.03	0.03	1.43	1.43	1.43
T_{11}- 50% NPK + 50% N-FYM	4.85	4.87	4.86	0.04	0.04	0.04	1.42	1.42	1.42
T_{12}- 50% NPK + 50% N- VC	4.85	4.88	4.87	0.03	0.03	0.03	1.43	1.43	1.43
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	4.84	4.85	4.85	0.03	0.03	0.03	1.42	1.42	1.42
T_{14}- FYM @ 10 t ha^{-1}	4.69	4.72	4.70	0.04	0.04	0.04	1.41	1.41	1.41
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	5.95	5.97	5.96	0.04	0.04	0.04	1.41	1.41	1.41
SEm±	0.11	0.10	0.08	0.005	0.004	0.003	0.01	0.01	0.01
CD(p=0.05)	0.33	0.29	0.21	NS	NS	NS	NS	NS	NS
Initial value	4.25	4.41	-	0.04	0.03	-	1.41	1.45	-

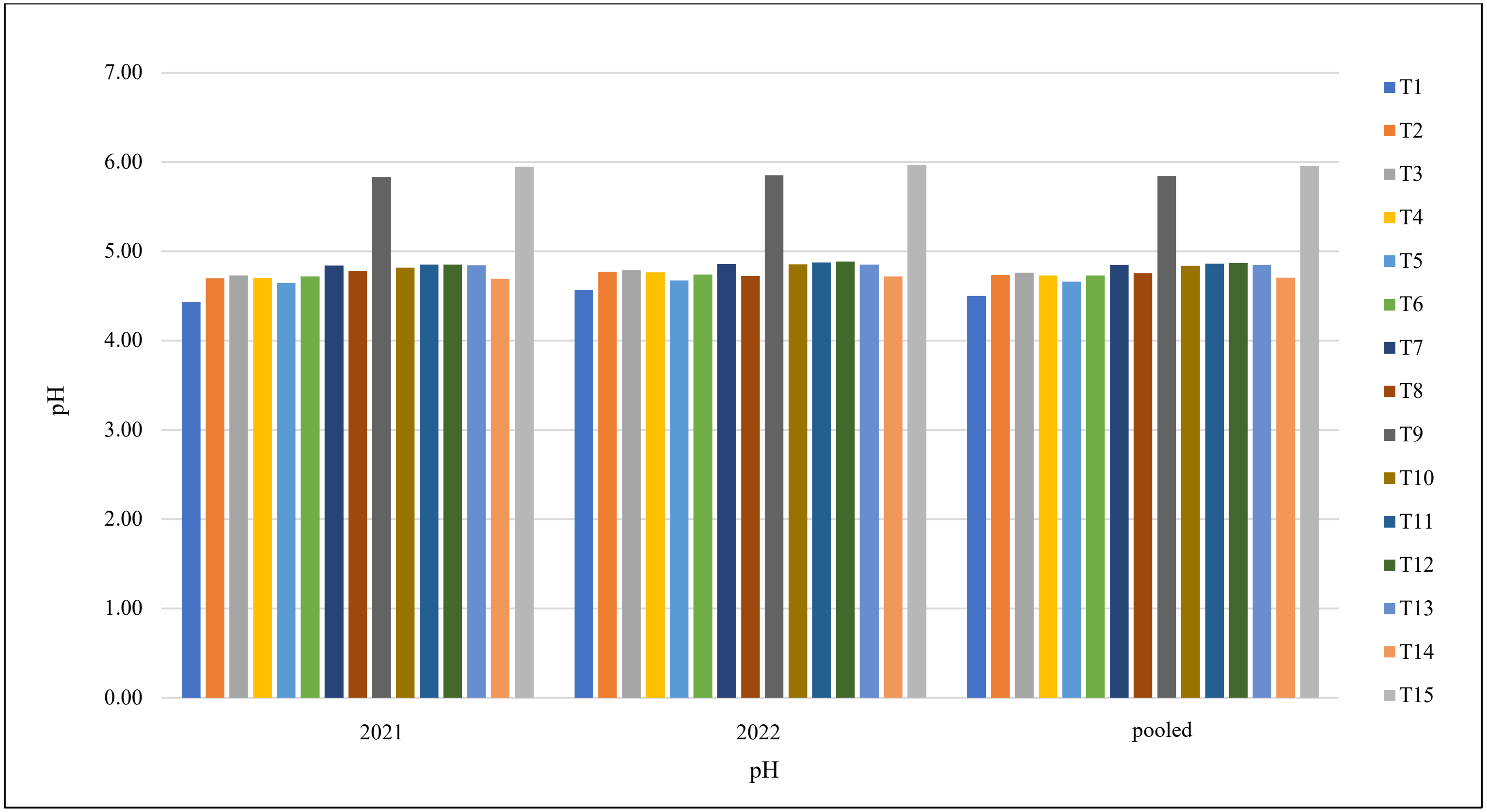


Fig 4.39: Effect of soil fertility management on pH in direct-seeded rice

4.3.4 Organic carbon (g kg^{-1})

The result obtained on organic carbon of post-harvest soil has been presented in table 4.21 and displayed figuratively in fig 4.40.

The results obtained during 2021 and 2022 revealed that maximum organic carbon for both years 2021 and 2022 was recorded in T_8 (18.93 and 18.97 g kg^{-1}) with pooled value of 18.95 g kg^{-1} while the minimum was recorded in T_1 (14.43 and 14.67g kg^{-1} for 2021 and 2022) with pooled value of 14.55 g kg^{-1} respectively. Application of T_8 increased the organic carbon by 30.24% over control T_1 from the pooled data. It was also observed that treatments which received organic manures recorded much higher organic carbon compare to sole recommended dose of fertilizers and no nutrient application in control. Treatment T_8 recorded the highest which was followed by T_{13} (18.85 and 18.90 g kg^{-1}), T_{15} (18.78 and 18.85 g kg^{-1}), T_{14} (18.68 and 18.75 g kg^{-1}) and T_7 (18.60 and 18.83 g kg^{-1}) for both the years 2021 and 2022 which were at par with T_8. The above treatments from the pooled data recorded an increase in organic carbon of about 29.75%, 29.34%, 28.65% and 28.65% respectively over control T_1. The significantly higher amount of organic carbon in the fertilized plots over control might be due to the greater yield associated with greater amount of root residues and stubbles of the crop added back to the soil. Kundu *et al*. (2007) reported that SOC content improved in fertilized plots as compared to unfertilized plots due to the C addition through the roots and crop residues, higher humification rate constant and lower decay rate. Jena and Pattanayak (2021) also recorded a gradual improvement in soil organic carbon stock under INM with application of treatment 100% NPK +FYM/Vermicompost with the advancements of year which could be possibly due to addition of organic manures and crop residues and carbon input excess due to decomposition. Integration nutrient management practices enhanced SOC had also been reported by Brar *et al*. (2015), Khan and Wani (2017). The importance of inclusion of sulphur and zinc in the treatment has been highlighted by the data recorded as treatment T_8 recorded the highest among all the treatments which is in conformity with the findings of Verma *et al*. (2014) who reported the highest soil organic carbon was recorded with the application of 100% NPK + 6 kg Zn + 20 kg S + 10 t FYM ha^{-1} which was relatively equivalent to the treatment T_8 in this study. Similar findings were reported by Majhi *et al*. (2016). Application of S along with Zn had a positive effect on soil organic carbon were also reported by Singh *et al*. (2012) and Majhi *et al*. (2016)

4.3.5 Total organic carbon (g kg^{-1})

The data related to total organic carbon has been portrayed in table 4.21 and graphically depicted in fig 4.41.

The perusal of the data recorded indicated that application of organic manures along with inorganic fertilizers significantly increased the total organic carbon of the post-harvest soil during both the years of experimentation. A critical examination of the data revealed that T_8 recorded the highest total organic carbon with 26.30 and 26.50 g kg^{-1} for both the years 2021 and 2022 with a pooled value 26.40 g kg^{-1} while the lowest total organic carbon was recorded in control T_1 with 22.03 and 22.18 g kg^{-1} for both the years 2021 and 2022 with pooled value 22.11 g kg^{-1} respectively. It was also observed that treatments which received organic manures recorded an increased in total organic carbon as compared to control and inorganic fertilizers alone. Treatments T_{13} (26.24 and 26.33 g kg^{-1}), T_{15} (26.20 and 26.28 g kg^{-1}) and T_{14} (26.13 and 26.23 g kg^{-1}) for both the years 2021 and 2022 recorded a higher value of total organic carbon and were also found to be statistically at par with T_8. Pooled value showed that application of treatment T_8 increased the total organic carbon by 19.40% over control while T_{13}, T_{15}, and T_{14} also recorded an increase of 18.90%, 18.67% and 18.40% over control T_1, respectively. Higher biomass and C input in 100% or 50% NPK inorganic fertilizer combined with FYM may have been due to the increased availability of deficient nutrients in the soil through organic manures. Srinivasarao *et al*. (2012) reported that build-up of C was highest in FYM 10 Mg ha^{-1} + 100% NPK (35%) followed by FYM 10 Mg ha^{-1} + 50% NPK, FYM 10 Mg ha^{-1} and NPK treatments where he observed a positive relationship between crop-residue C, external-C and total C inputs with the total SOC in the profile which indicated that C input positively influenced C stock in soil, as well as C build up percentage. The higher C retention in manure-amended plots was observed. Dhamak *et al*. (2020) reported that conjoint use of chemical fertilizers with FYM was found beneficial for maintaining high total carbon contents compared to the use of only chemical fertilizers. Similar findings were also observed by Pant *et al*. (2017) and Ghosh *et al*. (2021).

4.3.6 Cation exchange capacity [cmol (p$^+$) kg^{-1}]

The data pertaining to cation exchange capacity in soil as influenced by the different treatments under study has been presented in table 4.21 and graphically outlined in fig 4.42.

From the data recorded it was evident that significantly highest value was recorded from the application of treatment T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR with 14.27 cmol (p$^+$) kg^{-1} for the year 2021 and 14.35 cmol (p$^+$) kg^{-1} for the year 2022. However, with further evaluation of the data it was reported that treatment T_{15} was statistically at par with T_4 (13.11and 13.18 cmol (p$^+$) kg^{-1}), T_8 (13.50 and 13.53 cmol (p$^+$) kg^{-1}), T_9 (13.19 and 13.23 cmol (p$^+$) kg^{-1}), T_{11} (13.67 and13.71 cmol (p$^+$) kg^{-1}), T_{13} (13.99 and 14.04 cmol (p$^+$) kg^{-1}), and T_{14} (14.12, and 14.20 cmol (p$^+$) kg^{-1}) respectively for both the years of experimentation. The lowest value of cation exchange capacity was observed in the control T_1 with 9.15 and 9.26 cmol (p$^+$) kg^{-1} for 2021 and 2022 respectively.

The higher value of cation exchange capacity (CEC) in treatment T_{15} and other plots which also received organic sources can be assumed due to the application of more organic manures FYM which is known to improve the soil aggregate stability (Bilong *et al*., 2022), higher organic matter content (Aziz *et al*., 2019), serves as a reservoir for cations calcium (Ca), magnesium (Mg),

Table 4.21: Effect of soil fertility management on organic carbon, total organic carbon and CEC in direct seeded rice

Treatments	Organic carbon (g kg^{-1})			Total organic carbon (g kg^{-1})			CEC [cmol (p^+) kg^{-1}]		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	14.43	14.67	14.55	22.03	22.18	22.11	9.15	9.26	9.21
T_2- 100% NPK	16.00	16.33	16.17	24.23	24.33	24.28	12.04	12.12	12.08
T_3- 50% NPK	15.70	15.87	15.78	23.57	23.83	23.70	10.40	10.45	10.42
T_4- SSNM (109:30:46 NPK)	17.93	18.17	18.05	25.33	25.37	25.35	13.11	13.18	13.15
T_5- 100% NPK + Zn	18.23	18.43	18.33	25.80	25.88	25.84	12.93	13.01	12.97
T_6- 100% NPK + S	17.40	17.70	17.55	25.70	25.80	25.75	12.26	12.37	12.32
T_7- 100% NPK +Zn + S	18.60	18.83	18.72	26.03	26.27	26.15	12.80	12.85	12.83
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	18.93	18.97	18.95	26.30	26.50	26.40	13.50	13.53	13.52
T_9- 100% NPK + Liming @LR	18.00	18.40	18.20	26.00	25.73	25.87	13.19	13.23	13.21
T_{10}- 50% NPK + Azospirillum	17.40	17.53	17.47	24.77	24.87	24.82	12.33	12.35	12.34
T_{11}- 50% NPK + 50% N-FYM	17.48	17.60	17.54	25.97	26.05	26.01	13.67	13.71	13.69
T_{12}- 50% NPK + 50% N- VC	17.53	17.83	17.68	25.83	25.93	25.88	12.17	12.22	12.20
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	18.85	18.90	18.88	26.24	26.33	26.29	13.99	14.04	14.02
T_{14}- FYM @ 10 t ha^{-1}	18.68	18.75	18.72	26.13	26.23	26.18	14.12	14.20	14.16
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	18.78	18.85	18.82	26.20	26.28	26.24	14.27	14.35	14.31
SEm±	0.20	0.16	0.13	0.11	0.12	0.08	0.44	0.43	0.31
CD(p=0.05)	0.59	0.48	0.37	0.31	0.34	0.22	1.27	1.24	0.87
Initial value	15.2	17.3	-	23.50	25.68		10.57	12.60	-

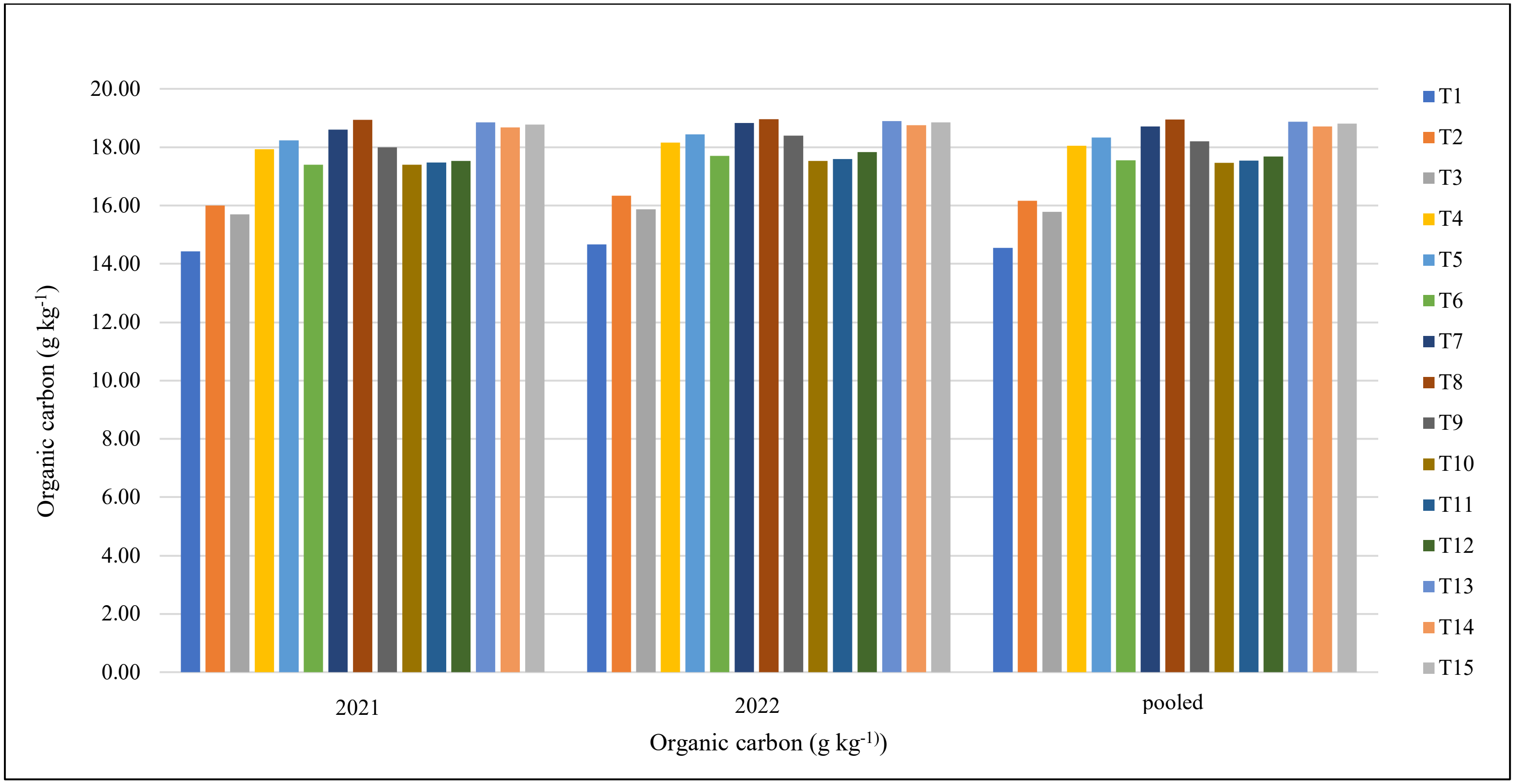


Fig 4.40: Effect of soil fertility management on organic carbon (g kg^{-1}) in direct-seeded rice

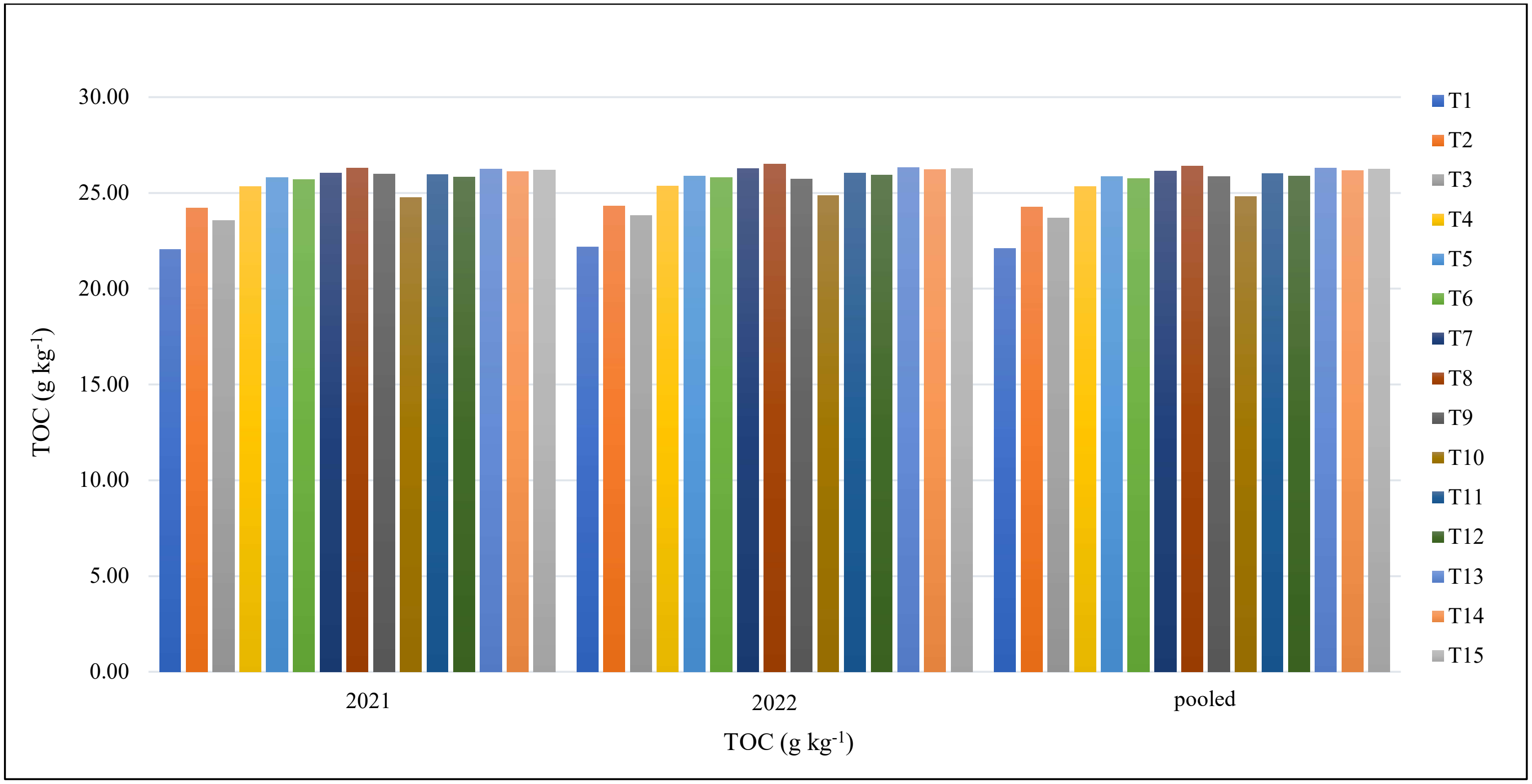


Fig 4.41: Effect of soil fertility management on TOC (g kg^{-1}) in direct-seeded rice

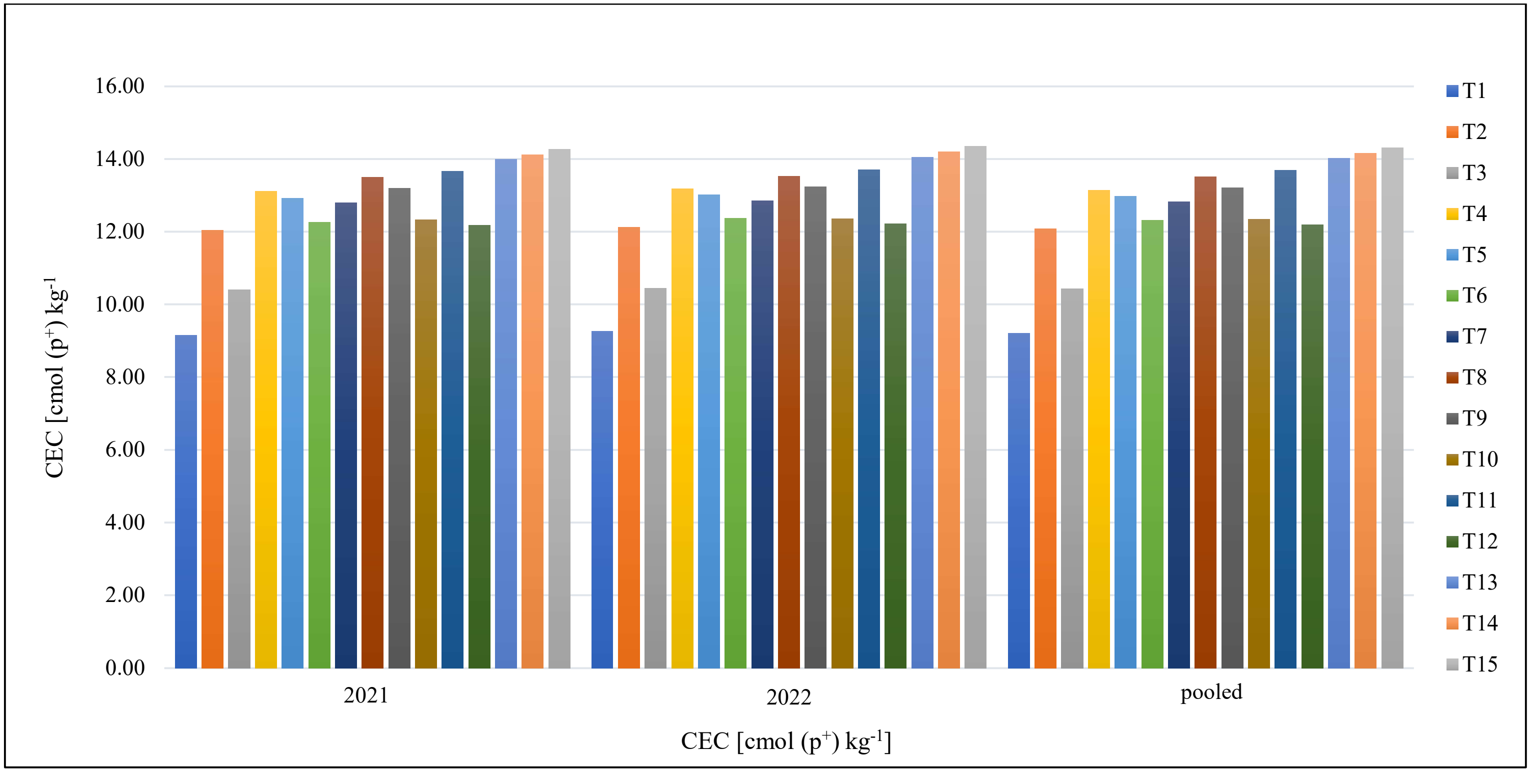


Fig 4.42: Effect of soil fertility management on CEC [cmol (p^+) kg^{-1}] in direct-seeded rice

potassium (K) and ammonium (NH_4^+), which are readily exchangeable with soil particles (Singh *et al.*, 2018), enhances CEC primarily through addition of organic matter and clay-humus complexes (Brady and Weil, 2008). The increase can also be attributed to enhanced growth of root mass as well as above ground parts. The nutrient supplying power of soil greatly depends on cation exchange capacity besides it influences the physical properties of the soil (Aziz *et al.*, 2019). The improvement in cation exchange capacity of the soil promotes soil fertility, nutrient retention, buffering capacity, reduce nutrient leaching and runoff and improving overall soil health. Pooled value of CEC ranged from 9.21 to 14.31 cmol (p^+) kg^{-1} where treatment T_{15} increase to an extent of 55.37% over control. Further evaluation among the treatments also revealed that treatment T_{15} had an increase of about 4. 35% over T_{13} (13.69 cmol (p^+) kg^{-1}) and 5.84% over T_8 (13.52 cmol (p^+) kg^{-1}) and both the treatments were statistically at par with T_{15}. The results obtained in this study was evident that treatments which had an integration of fertilizers and organic source or organic source alone had higher cation exchange capacity as compared to fertilizers alone and control which advocates the need for incorporation of organic sources for better nutrient availability.

4.3.7 Available nitrogen (kg ha^{-1})

The data regarding the available nitrogen in the soil after crop harvest has been laid out in table 4.22 and figuratively displayed in fig 4.43.

The data obtained revealed that application of treatment T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1} recorded the highest available nitrogen with the value of 285.12 kg ha^{-1} and 287.26 kg ha^{-1} for the year 2021 and 2022 while the pooled value recorded 286.19 kg ha^{-1} respectively. The lowest value was recorded with the control T_1 with 243.32 kg ha^{-1} and 248.24 kg ha^{-1} for both the years of experimentation with a pooled value 245.78 kg ha^{-1} respectively. A critical examination of the obtained data revealed that in 2021 treatment T_8 was significantly the highest which was followed by treatment T_7 with 280.51 kg ha$^-$

^{1} however T_7 was at par with treatments T_9 (276.67 kg ha^{-1}), T_{13} (278.80 kg ha^{-1}), T_{15} (277.78 kg ha^{-1}) and similarly in the year 2022 treatment T_8 was the highest but statistically at par with T_7 (283.14 kg ha $^{-1}$). With further evaluation it was observed that T_7 was at par with T_{13} (281.02 kg ha^{-1}), T_{14} (279.78 kg ha^{-1}), and T_{15} (280.60 kg ha^{-1}). Application of treatment T_8 100% NPK +Zn +S + FYM @ 5t ha^{-1} increased the soil available nitrogen to the tune of 17.17% and 15.71% over control for both the years 2021 and 2022 and pooled value of about 16.70% over control respectively.

It can be observed in this study that providing a balanced nutrition to the soil through both organic and inorganic sources increased the available N content of the soil whereas a reduction in any of the nutrient resulted in a lower value due to the imbalanced nutrient management. Additionally, the integration of inorganic and organic proved to be statistically higher as compared to inorganic fertilizers alone or organic sources alone as inorganic fertilizer release nutrient in readily available form during the early growth of the plant while the organic sources like FYM due to its slow releasing nature of nutrient helped in the latter part of the crop development making nutrients sufficiently available in the soil pool. The release of organic acids and other microbial products through mineralization of organic matter might have influenced the availability of the nutrient (Katyal *et al*., 2003). Upadhyay and Vishwakarma (2014) also observed that available N content was higher by providing balanced nutrition to the soil through organic and inorganic source under rice-wheat cropping sequence while the lower content was noted with insufficient nutrient application. Data further showed that substitution of N at higher rate (100%) produced significantly higher N in soil than 50% substitution rate of respective source. This is in conformity with Swarup and Yaduvanshi (2000) and Kumar *et al*. (2010) where 100% was considered to have performed better than other levels of NPK. Increase in available nitrogen can also be attributed to the direct addition through organics FYM which enhanced the soil microbes multiplication which helped in conversion of organically bound N into inorganic form, mineralization and build-up of higher available N in the soil (Tolunar and Badanur, 2003). It was revealed that application of FYM along with 100% NPK + S + Zn significantly increased the available N content in soil over other treatments. Similar findings are reported by Kumar and Singh, (2010) and Kumari *et al*. (2017).

4.3.8 Available phosphorus (kg ha^{-1})

The results for available phosphorus in soil after the harvest of the crop has been presented in table 4.22 and figuratively displayed in fig 4.44.

Data revealed that application of treatment T_8 - 100% NPK +Zn +S + FYM @ 5t ha^{-1} recorded the highest available phosphorus 18.15 kg ha^{-}1 for the year 2021 and 18.22 kg ha^{-1} for 2022 while the lowest was recorded in control T_1 with values of 8.22 kg ha^{-1} and 8.34 kg ha^{-1} for both the years of experimentation respectively. The treatment T_8 recorded the highest followed by T_7 -100% NPK +Zn +S with values 17.93 kg ha^{-1} and 18.03 kg ha^{-1} for 2021 and 2022 and T_{13} - 50% NPK + 25% N-FYM + 25% N-VC with values 17.28 kg ha^{-1} and 17.35 kg ha^{-1} for both years 2021 and 2022, respectively. However, with critical evaluation it was found that T_8 was statistically at par with T_7 for both the years respectively as both treatments received the same dose of phosphorus nutrient during crop growth period. Pooled value revealed that treatment T_8 increased the soil available phosphorus to an extent of 119.56% over control T_1 which had no nutrient application. The higher value of T_8 in comparison with control and other treatments may be due to application of inorganic fertilizers along with FYM which was responsible for the release of organic acids during decomposition which in turn helped in the release of phosphorus through solubilizing action of native phosphorus in soil (Sharma and Subehia, 2014). The organic matter also forms a protective cover on sesquioxide and makes them inactive thus reduces the phosphate fixing capacity of the soil, which ultimately, helps in release of ample quantity of phosphorus (Urkurkar *et al*., 2010). Organic manures enhance labile P in soil through complexation of cations Ca^{2+} and Mg^{2+}

when applied in combination with inorganic fertilizers (Urkurkar *et al*., 2010). Manure also helps in producing intermediate compounds that interact with phosphorus-fixing cations such as aluminium, iron, etc., thereby reducing P adsorption capacity (Tamado and Mitiku, 2017). The increased available P in the present study is in conformity with the findings of Thamaraiselvi *et al*. (2012) who reported that highest concentration of phosphorus was with the combined application of FYM and 100 kg P_2O_5 ha^{-1}. Tamado and Mitiku (2017) observed an increased in available phosphorus with the treatment FYM @ 5 t ha^{-1} in combination with 75% inorganic NP fertilizers by 70.5 and 78.2% in two crop varieties over sole 100% recommended rates of N and P. Organic fertilization also stimulates the activities of soil microorganisms and phosphatase, accelerating the rate of mineralization (Song *et al*., 2022).

4.3.9 Available potassium (kg ha^{-1})

Data pertaining to available potassium in soil after harvest of the crop with the treatments under study has been depicted in table 4.22 and displayed graphically in fig 4.45.

It was evident from the data recorded that treatment T_8 obtained the highest available potassium with 116.27 kg ha^{-1} and 117.93 kg ha^{-1} for both the years 2021 and 2022 while the lowest was reported from the control T_1 which had no nutrient application with values 96.13 kg ha^{-1} and 96.40 kg ha^{-1} respectively. In the year 2021, after critical evaluation treatment T_8 was followed by treatments T_7 (114.53 kg ha^{-1}), T_{13} (112.69 kg ha^{-1}), however, T_8 was at par with T_7, while T_7 was also found to be statistically at par with T_5 (111.56 kg ha^{-1}), T_9 (111.52 kg ha^{-1}) and T_{13} (112. 69 kg ha^{-1}). On the other hand, for the year 2022, treatment T_8 was significantly the highest which was followed by T_5 (113.47 kg ha^{-1}), T_{13} (112.37 kg ha^{-1}) and T_7 (112.00 kg ha^{-1}) where after statistical evaluation T_5 was found to be at par with T_7 and T_{13} respectively. Pooled value showed that application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) increased the soil available potassium to an extent of 21.63%

over control T_1, 3.38% over T_7, 4.06% over T_{13}, 4.08% over T_5 and 5.83% over T_9 respectively.

Maximum potassium availability was obtained through T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) followed by T_7 (100% NPK +Zn +S). The higher availability of potassium with FYM may be ascribed to the reduction in K fixation and release of K due to the interaction of organic matter with clay (Pant *et al*., 2017) and as organic fertilization stimulates/improves the microbial conversion and activity of organic K into inorganic K (Yu *et al*., 2023). Shahid *et al*. (2015) observed that available K was highest in NK+FYM followed by NPK+FYM treatment, demonstrating the role of chemical fertilizers and organic manure in the supplementation of K in the soil while also suggesting the continuous addition of K which would improve the soil available K supply. With further evaluation, treatment T_{13} (50% NPK + 25% N-FYM + 25% N-VC) recorded a lower value compared to T_8 even though it had organic sources in its components which might due to the exclusion of S from the fertilizer dose. Pant *et al*. (2017) reported that exclusion of either PK of K or S from the fertilizer dose reduced the K availability. Increase in available potassium due to the addition of organic manures FYM may be ascribed to the reduction of K-fixation and release of K due to interaction of organic matter with clays, besides the direct addition to the soil (Kumari *et al*., 2017), as compared to control and other treatments which had inorganic fertilizers or organic manures alone that experienced a reduction in available K probably due to higher potassium mining from the soils.

4.3.10 Available sulphur (kg ha^{-1})

The data pertaining to available sulphur in soil after harvest of the crop are presented in table 4.23 and portrayed in fig 4.46.

It was observed that the maximum available sulphur was obtained with the application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) with values 15.70 kg ha^{-1} for the year 2021 and 15.72 kg ha^{-1} for the year 2022 while

Table 4.22: Effect of soil fertility management on available N, P, and K in direct seeded rice

Treatments	Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})			Available K_2O (kg ha^{-1})		
	2021	2022	pooled	2021	2022	pooled	2021	2022	pooled
T_1- Control	243.32	248.24	245.78	8.22	8.34	8.28	96.13	96.40	96.27
T_2- 100% NPK	260.22	262.39	261.31	10.65	10.75	10.70	99.20	100.13	99.67
T_3- 50% NPK	256.89	257.96	257.43	9.26	9.39	9.32	98.01	98.01	98.01
T_4- SSNM (109:30:46 NPK)	269.83	274.50	272.17	14.08	14.20	14.14	109.93	107.15	108.54
T_5- 100% NPK + Zn	262.02	265.18	263.60	15.02	15.37	15.19	111.56	113.47	112.51
T_6- 100% NPK + S	264.57	267.88	266.23	12.91	13.03	12.97	106.57	106.87	106.72
T_7- 100% NPK +Zn + S	280.51	283.14	281.83	17.93	18.03	17.98	114.53	112.00	113.27
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	285.12	287.26	286.19	18.15	18.22	18.18	116.27	117.93	117.10
T_9- 100% NPK + Liming @LR	276.67	278.26	277.47	14.52	14.62	14.57	111.52	109.76	110.64
T_{10}- 50% NPK + Azospirillum	256.84	259.24	258.04	11.65	11.71	11.68	99.44	103.81	101.63
T_{11}- 50% NPK + 50% N-FYM	272.73	275.08	273.91	13.41	13.50	13.46	108.53	107.89	108.21
T_{12}- 50% NPK + 50% N- VC	260.20	263.19	261.69	12.66	12.74	12.70	106.52	106.40	106.46
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	278.80	281.02	279.91	17.28	17.35	17.31	112.69	112.37	112.53
T_{14}- FYM @ 10 t ha^{-1}	275.24	279.78	277.51	12.22	12.34	12.28	104.00	104.16	104.08
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	277.78	280.60	279.19	13.20	13.34	13.27	106.88	107.15	107.01
SEm±	1.56	1.56	1.10	0.13	0.10	0.08	0.72	0.92	0.58
CD(p=0.05)	4.53	4.52	3.13	0.37	0.29	0.23	2.09	2.66	1.65
Initial value	256.42	264.86	-	9.05	12.42	-	96.60	106.33	-

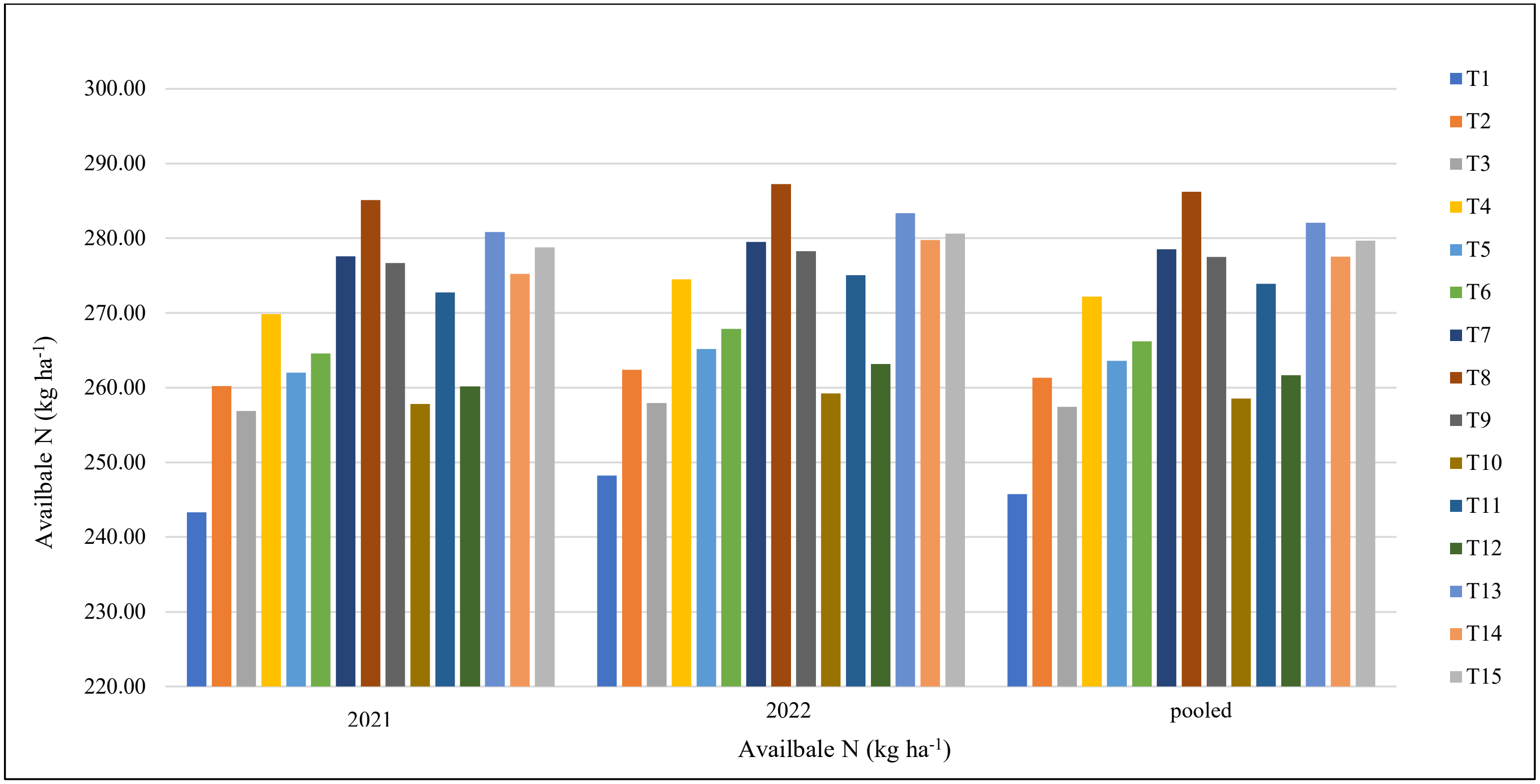


Fig 4.43: Effect of soil fertility management on available N (kg ha^{-1}) in direct-seeded rice

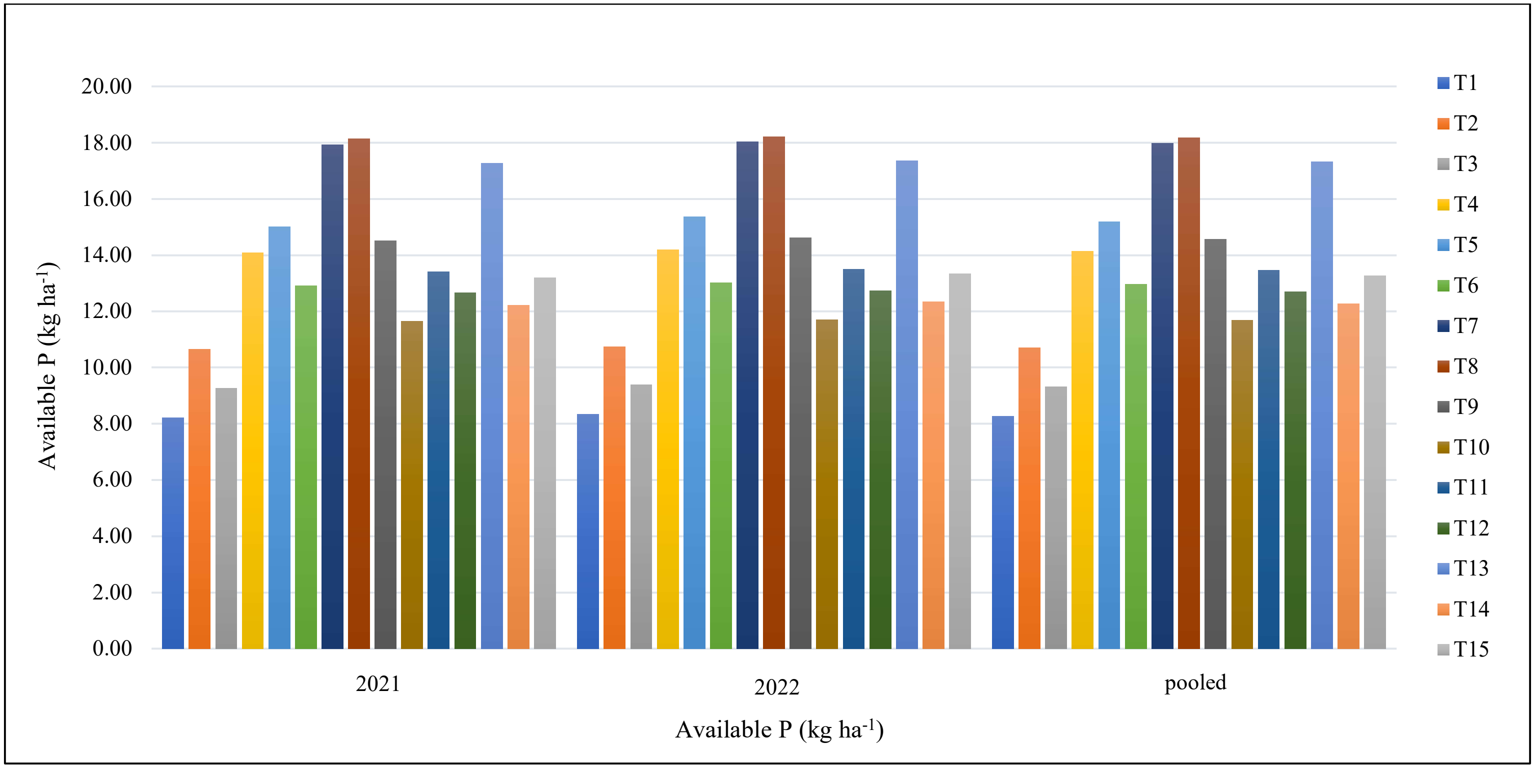


Fig 4.44: Effect of soil fertility management on available P (kg ha^{-1}) in direct-seeded rice

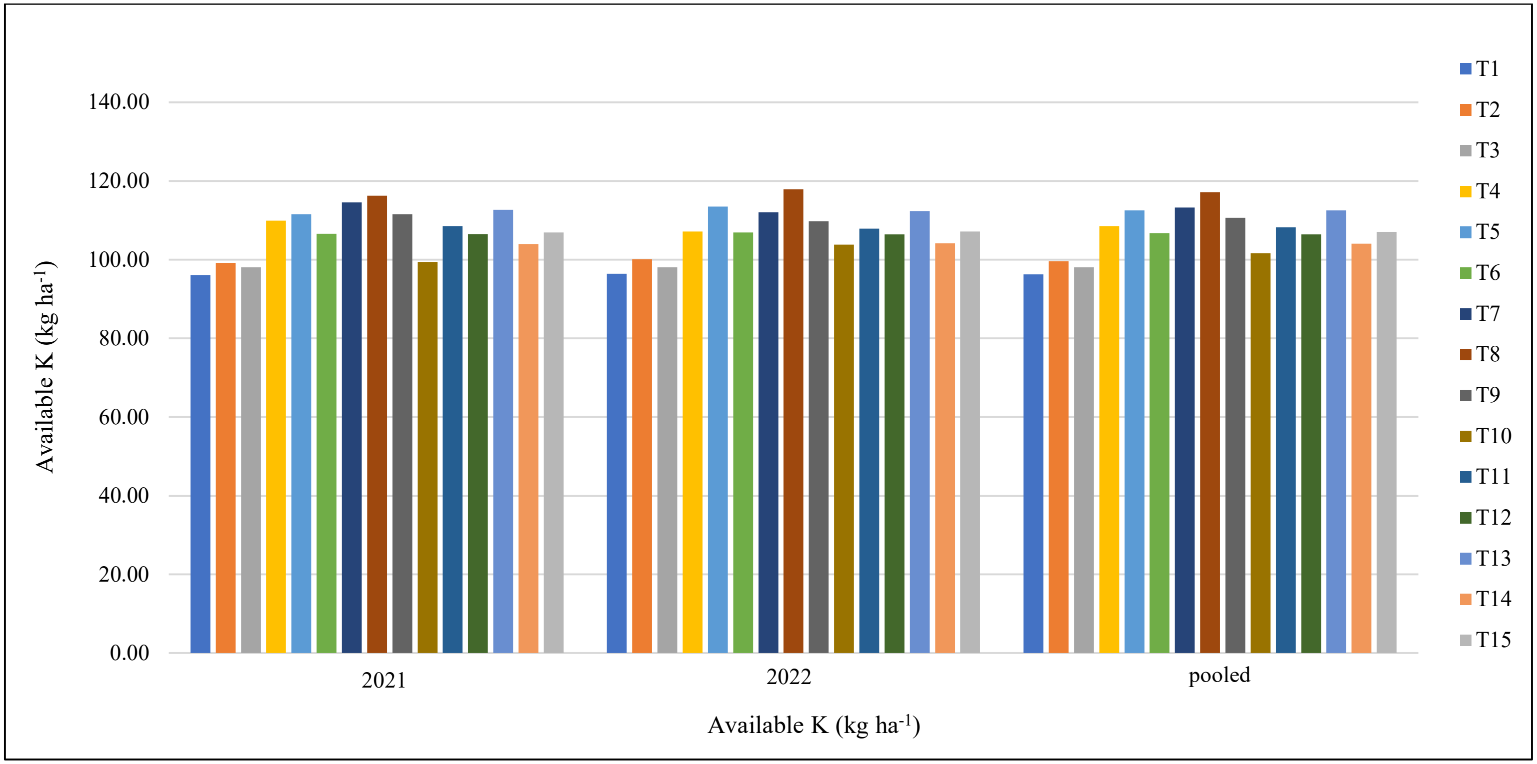


Fig 4.45: Effect of soil fertility management on available K (kg ha^{-1}) in direct-seeded rice

the lowest was recorded in control T_1 with 13.19 kg ha^{-1} and 13.21 kg ha^{-1} respectively. A perusal of data further indicated that treatment T_8 was at par with T_7 (15.67 and 15.70 kg ha^{-1}), T_6 (15.56 and 15.61 kg ha^{-1}), T_5 (15.42 and 15.45 kg ha^{-1}), T_9 (15.36 and 15.38 kg ha^{-1}), T_{12} (15.37 and 15.40 kg ha^{-1}) for the year 2021 and 2022 while was also at par with T_{13} (15.35 kg ha^{-1}) for the year 2022 respectively. Pooled value revealed that available sulphur had increased to an extent of 19.01% by treatment T_8 over control T_1, likewise for other treatments T_7 -100% NPK +Zn +S, T_6 -100% NPK +Zn, T_5 -100% NPK +S, T_9 -100% NPK + Liming @LR, T_{12} -50% NPK + 50% N- VC and T_{13} -50% NPK + 25% N-FYM + 25% N-VC it had enhanced the available sulphur in soil by 18.86%, 18.10%, 16.96%, 16.43%, 16.59% and 16.21% over control T_1, respectively.

Evidently, the sulphur treated plots reported a higher sulphur content in soil and with the addition of FYM along with the inorganic fertilizers it substantially enhanced the soil available sulphur in comparison to other treatments and control T_1. Primarily due to no addition of sulphur it recorded noticeably a lower amount of sulphur nutrient in soil and also because of low organic matter content in the treatments as sulphur is known to be an integral part of soil organic matter (Kumari *et al*., 2017). Omission of sulphur from fertilizer dose can drastically reduce the available sulphur in soil and may show at par with control (Pant *et al*., 2017). Sulphur is also another essential secondary nutrient that is affected by soil acidity. In acidic soils, sulphur can be converted to sulphates, which are highly soluble and can be readily leached from the soil. This may result in sulphur deficiencies in plants and decreased yield (Singh *et al*., 2015). Apart from sulphur treated plots, it has been observed that organic integration along with inorganic fertilizers recorded comparatively higher S than sole inorganic fertilizers which emphasize the need for organic integration as continuous application of inorganic fertilizers may result in increased acidity. The result was in concordance with the study carried out by Singh *et al*. (2023).

4.3.11 Exchangeable calcium [cmol (p^+) kg^{-1}]

Data pertaining to exchangeable calcium in soil after harvest of crop has been presented in table 4.23.

The data obtained from the study clearly showed that the exchangeable calcium of the soil was recorded highest in the treatment T_9 and T_{15} where T_9 recorded highest in the year 2021 with 1.25 cmol (p^+) kg^{-1} while T_{15} recorded the highest for the year 2022 with a value 1.26 cmol (p^+) kg^{-1} respectively while the lowest was observed in control T_1 with 1.16 cmol (p^+) kg^{-1} and 1.17 cmol (p^+) kg^{-1} for both the years of experimentation. Pooled value also varied between 1.16 to 2.25 cmol (p^+) kg^{-1}. Lime treated plots (T_9 and T_{15}) recorded higher exchangeable calcium as compared to other treatments under study and was followed by T_8 (1.24 cmol (p^+) kg^{-1}), T_{11} (1.24 cmol (p^+) kg^{-1}) and T_{13} (1.25 cmol (p^+) kg^{-1}). It was also observed that treatments T_9, T_{15}, T_8, T_{11} and T_{13} respectively were able to record about 7.75%, 8.62%, 6.89%, 6.89% and 7.75% increase in exchangeable calcium in soil over control T_1. However, it was not able to reach the statistical difference and thus did not show any significant effect in soil after harvest.

Although almost all the treatments could not show any significant differences statistically, it certainly did not show a decreasing trend in both the years but maintain a linear increment in exchangeable Ca. Critical examination among the treatments revealed that treatments which received organic sources had a higher exchangeable Ca content like T_8, T_{11} and T_{13} which may be due to the organic manures producing organic acids during decomposition which enhanced the solubility of native Ca and Mg and its retention by organic colloids. The increased availability may be due to the chelates of higher stability with organic ligands which have lower susceptibility to adsorption fixation and precipitation in the soil (Diwale *et al*., 2020). However, the sub-optimal content of Ca observed with the treatments under study in both years might be due to the chemical fertilizer application which brought about the tendency of calcium to

Table 4.23: Effect of soil fertility management on available S and exchangeable Ca in direct seeded rice

Treatments	Available S (kg ha^{-1})			Exchangeable Ca [cmol (p^+) kg^{-1}]		
	2021	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	13.19	13.21	13.20	1.16	1.17	1.16
T_2- 100% NPK	14.35	14.38	14.36	1.18	1.19	1.19
T_3- 50% NPK	14.25	14.26	14.26	1.17	1.18	1.18
T_4- SSNM (109:30:46 NPK)	14.85	14.88	14.86	1.19	1.20	1.20
T_5- 100% NPK + Zn	15.42	15.45	15.44	1.22	1.23	1.23
T_6- 100% NPK + S	15.56	15.61	15.59	1.20	1.21	1.21
T_7- 100% NPK +Zn + S	15.67	15.70	15.69	1.22	1.23	1.22
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	15.70	15.72	15.71	1.23	1.24	1.24
T_9- 100% NPK + Liming @LR	15.36	15.38	15.37	1.25	1.25	1.25
T_{10}- 50% NPK + Azospirillum	14.85	14.91	14.88	1.21	1.23	1.22
T_{11}- 50% NPK + 50% N-FYM	14.43	14.46	14.45	1.23	1.24	1.24
T_{12}- 50% NPK + 50% N- VC	15.37	15.40	15.39	1.22	1.22	1.22
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	15.33	15.35	15.34	1.24	1.25	1.25
T_{14}- FYM @ 10 t ha^{-1}	14.67	14.69	14.68	1.23	1.23	1.23
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	15.18	15.22	15.20	1.25	1.26	1.26
SEm±	0.12	0.13	0.09	0.03	0.03	0.02
CD(p=0.05)	0.35	0.37	0.25	NS	NS	NS
Initial value	14.26	14.60	-	1.24	1.23	-

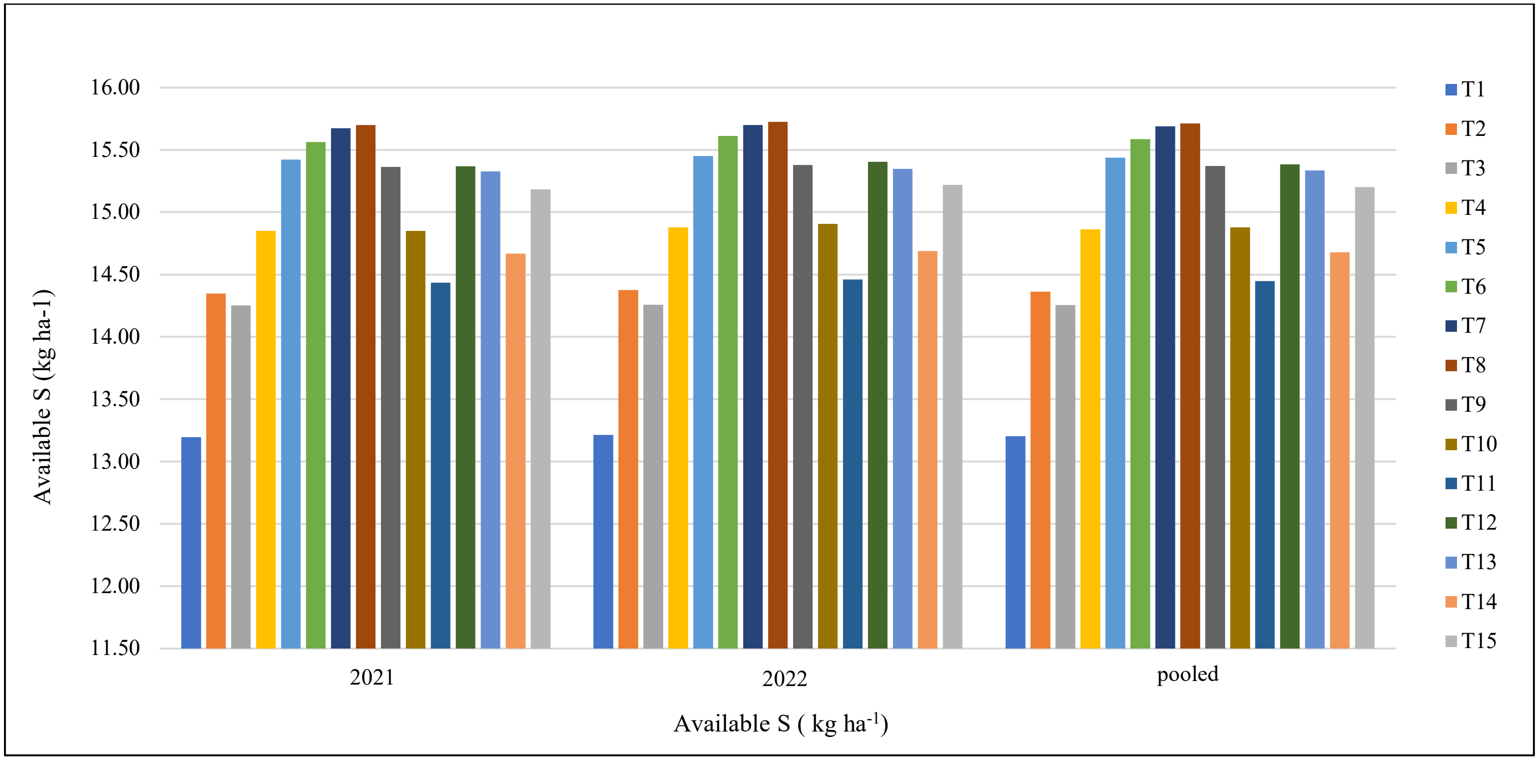


Fig 4.46: Effect of soil fertility management on available S (kg ha^{-1}) in direct-seeded rice

offset the hydrolysis of the urea fertilizer to reduce soil acidity by increasing the amount of cation exchange capacity (Jones *et al*., 2013). Another reason might also be due to the various processes interconnected with plant uptake and reaction with fertilizers brought about the loss of calcium from the soil and thus the lower exchangeable calcium in the post-harvest soil (Nemera *et al*., 2018).

4.3.12 Available zinc (mg kg^{-1})

Perusal of data on available zinc in soil after crop harvest with the treatments under study are presented in table 4.24 and depicted in fig 4.47.

Results revealed that application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) recorded the highest soil available zinc 1.35 kg ha^{-1} for 2021 and 1.36 kg ha^{-1} for 2022 while the lowest was recorded in the control treatment T_1 with 1.05 kg ha^{-1} and 1.06 kg ha^{-1} for both the years of experimentation, respectively. Further examination of the obtained revealed that zinc treated plot recorded higher available zinc in soil particularly T_5 - 100% NPK +Zn (1.30 and 1.33 kg ha^{-1}), T_6 - 100% NPK +Zn +S (1.22 and 1.24 kg ha^{-1}) and T_7 - 100% NPK+S (1.25 and 1.26 kg ha^{-1}) as compared to the other treatments which had no source of zinc application. Apart from the zinc receiving treatments, T_3 - 50% NPK (1.19 and 1.20 kg ha^{-1}) and T_{13} - 50% NPK + 25% N-FYM + 25% N-VC (1.17 and 1.21 kg ha^{-1}) also recorded a higher value which was statistically at par with each other. Pooled value varied between the range of 1.06 to1.36 kg ha^{-1} and revealed that treatments T_8 recorded an increase in soil available zinc of about 28.30% over control T_1. Similarly, treatments T_5, T_6 and T_7 also recorded 25.24%, 16.03% and 18.86% over control, respectively.

Significant increase in soil DTPA-extractable Zn content was found with application of zinc at a suitable recommended rate (10 kg ha^{-1}) showing a positive effect of Zn fertilization. This recognized the importance of zinc fertilization along with complete fertilization of primary nutrients. Shahane *et al*. (2019) also reported that application of zinc @ 5 kg ha^{-1} recommended dose led to increase in soil available zinc. Careful observation with the recorded data discloses that even amongst the zinc treated plots treatments T_8 recorded a higher value of available zinc in soil which may be regarded due to the integration of FYM as organic sources are known to be beneficial for maintaining the micronutrient status in soil as compared to sole application of inorganic fertilizers which may result in mining of the nutrient leading to its depletion. Kumari *et al*. (2017) reported that addition of organic sources like FYM with fertilizers enhanced the microbial activity in the soil and consequently the release of organic substances like chelating agents which prevented micronutrients from precipitation, fixation, oxidation and leaching. A close examination of the data indicates significant increase in zinc content with increase in organic content. The availability of zinc increased significantly with increase in organic carbon because zinc form soluble complexes (chelates) with soil organic matter component. This is in conformity with the findings of Meena and Mathur (2017). It was also observed that apart from control T_1, lime treated plots T_9 and T_{15} recorded lower value next to control which might be due to the increase in $CaCO_3$ reducing the availability of zinc. As the pH increases due to $CaCO_3$ content, zinc tends to form insoluble compounds such as $Zn(OH)_2$ and $ZnCO_3$ which can reduce the availability of zinc. The results are in concordance with the findings of Mehra and Jat (2007).

4.3.13 Available iron (mg kg^{-1})

The data related to available iron in soil after harvest of the crop have been summarized in table 4.24.

It was clearly observed from the data recorded that available iron in soil ranged from 32.78 mg kg^{-1} and 32.75 mg kg^{-1} to 33.97 mg kg^{-1} and 33.74 mg kg^{-1} for both the years, 2021 and 2022, respectively. Although the available iron increased over the years with the application of treatments however, it was not able to show any significant difference among the treatments under study and therefore resulted non-significant. With critical evaluation of the recorded data, it has been observed that application of T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-}

^{1}) for both the years 2021and 2022 gave highest available iron which recorded about 3.63% and 3.02% increase over control T_1 which had no fertilizer nutrient application. It was also evident that plots which had organic sources especially with FYM recorded an increase in available iron over treatments which had only inorganic nutrient application. This elucidated the fact that FYM had a role in enhancing the available iron in the soil. The higher availability of micronutrients in soil with the application of organic manures might be due to complexing properties of organic manures with the metal ions which prevent precipitation and fixation and also due to production of chelating agents with the decay of organic manures which have the ability to transform solid phase of micronutrients cations into soluble metal complexes (Raut *et al*., 2021). A close scrutiny of the data revealed that treatments which had organic sources recorded an increase in available iron in soil as it positively correlated with increase in organic carbon of soil. Meena and Mathur (2017) also reported that with increase in soil CEC, available iron also increases due to more availability of exchange sites on soil colloids.

4.3.14 Available manganese (mg kg^{-1})

The data for available manganese in soil after harvest of the crop are displayed in table 4.25.

Available manganese recorded an increase with the application of different treatments over the both years as the values varied from 12.39 mg kg^{-1} and 12.41 mg kg^{-1} with control T_1 to 13.54 mg kg^{-1} and 13.56 mg kg^{-1} with T_8 during both the year 2021 and 2022 respectively. Pooled value of treatment T_8 exhibited that available manganese increased to an extend of about 9.26% over control (T_1). The reason for low available manganese in control plot primarily owing to no nutrient application. It has also been observed that the treatments which had organic sources of nutrients in composition recorded a higher available manganese as compared to treatments which had only inorganic fertilizers, therefore organic sources like FYM could have been the beneficial factor for the enhanced micronutrient in the soil. The higher values might also be attributable to the high content of organic carbon as well as finer fraction of soils leading to increase in the surface area for ion exchange and hence, contributed to higher amount of micronutrient in soils (Sharma *et al*., 2003; Sireesha *et al*., 2019).

Treatments like T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) with 13.54 and 13.56 mg kg^{-1}, T_{11} (50% NPK + 50% N-FYM) with 12.93 and 12.98 mg kg^{-1}, T_{12} (50% NPK + 50% N- VC) with 13.45 and 13.47 mg kg^{-1}, T_{13} (50% NPK + 25% N-FYM + 25% N-VC) with 13.43 and 13.48 mg kg^{-1}, T_{14} (FYM @ 10 t ha^{-1}) with 13.38 and 13.42 mg kg^{-1} and T_{15} (FYM @ 10 t ha^{-1} + Liming @ LR) with 13.43 and 13.46 mg kg^{-1} for both years 2021 and 2022 recorded a higher value of available manganese in the soil after harvest of the crop. Among the organic manure integrated treatments T_{11} had a lower value as compared to other treatments but it recorded 4.35% and 4.59% increase over control for both years 2021 and 2022 respectively. Also, a positive correlation between available manganese and organic carbon content was observed, as the organic carbon is known to enhanced the availability of micronutrients in soil (Sidhu and Sharma, 2010). On the other hand, the availability of manganese was reduced due to the presence of $CaCO_3$ as observed in lime treated plot T_9 which might be due to formation of soluble compounds like $MnCO_3$ or Mn $(OH)_2$. This maybe arguable with T_{13} which was also lime treated but due to the high organic carbon content, which may have decreased the pH of the soil as high pH favours the formation of less soluble organic complexes of Mn, which reduced the availability of Mn and retarded the activity of soil microorganism which oxidizes soluble Mn^{2+} (Singh *et al*., 2013). However, the values obtained for soil available manganese did not prove to show any significant difference statistically thus remained non-significant.

4.3.15 Available copper (mg kg^{-1})

The data pertaining to available copper in soil after harvest of the crop are presented in table 4.25.

It was evident from the data obtained that available copper in soil reported to have increased over both the years of experimentation 2021 and 2022 as values varied from (T_1) 1.25 and 1.27 mg kg^{-1} to (T_8) 1.58 and 1.60 mg kg^{-1}. Application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) recorded the highest as the treatment had an integration of both inorganic and organic source of nutrients which reported to have increased to an extent of about 26.4% and 25.98% over control for both the years 2021 and 2022, respectively. Further examination of the results revealed that treatments which had organic source like FYM proved to have a higher accumulation of available copper in the soil unlike treatments which had only inorganic fertilizers. Low molecular weight compounds liberated during decay of plant and animal residues as well as those applied with sewage sludge may greatly increase the availability of Cu to plants (Alina, 2011). The available copper also increased with increased in organic carbon. The organic acid molecules present in organic matter solubilise Cu^{2+} ions by chelation and complexion and as a result of this organic binding, there is more dissolved copper in soil solution than in the absence of organic matter. This was in conformity with the findings of Yadav (2008) and Kumar and Babel (2011) where they reported that available micronutrients in soil increased with the increase in soil organic carbon content, finer fractions of soil due to aggregate formation in the presence of high organic matter and reduces with high pH. However, the available copper data also failed to show any significant difference among the treatments under study and thus reported to have been statistically non-significant.

Table 4.24: Effect of soil fertility management on available Zn and Fe in direct seeded rice

Treatments	Available Zn (mg kg^{-1})			Available Fe (mg kg^{-1})		
	2021	2022	pooled	2021	2022	pooled
T_1- Control	1.05	1.06	1.06	32.78	32.75	32.77
T_2- 100% NPK	1.14	1.16	1.15	33.14	33.10	33.12
T_3- 50% NPK	1.19	1.20	1.20	33.28	33.21	33.25
T_4- SSNM (109:30:46 NPK)	1.08	1.10	1.09	33.12	33.05	33.08
T_5- 100% NPK + Zn	1.30	1.33	1.32	33.33	33.30	33.31
T_6- 100% NPK + S	1.22	1.24	1.23	33.25	33.12	33.19
T_7- 100% NPK +Zn + S	1.25	1.26	1.26	33.52	33.51	33.52
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	1.35	1.36	1.36	33.97	33.74	33.86
T_9- 100% NPK + Liming @LR	1.08	1.09	1.09	32.81	32.76	32.78
T_{10}- 50% NPK + Azospirillum	1.15	1.17	1.16	33.54	33.50	33.52
T_{11}- 50% NPK + 50% N-FYM	1.15	1.19	1.17	33.70	33.60	33.65
T_{12}- 50% NPK + 50% N- VC	1.12	1.13	1.13	33.58	33.51	33.55
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	1.17	1.21	1.19	33.42	33.38	33.40
T_{14}- FYM @ 10 t ha^{-1}	1.12	1.16	1.14	33.33	33.27	33.30
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	1.07	1.09	1.08	32.93	32.87	32.90
SEm±	0.01	0.01	0.01	0.48	0.48	0.34
CD(p=0.05)	0.03	0.03	0.02	NS	NS	NS
Initial value	1.10	1.18	-	32.54	33.25	-

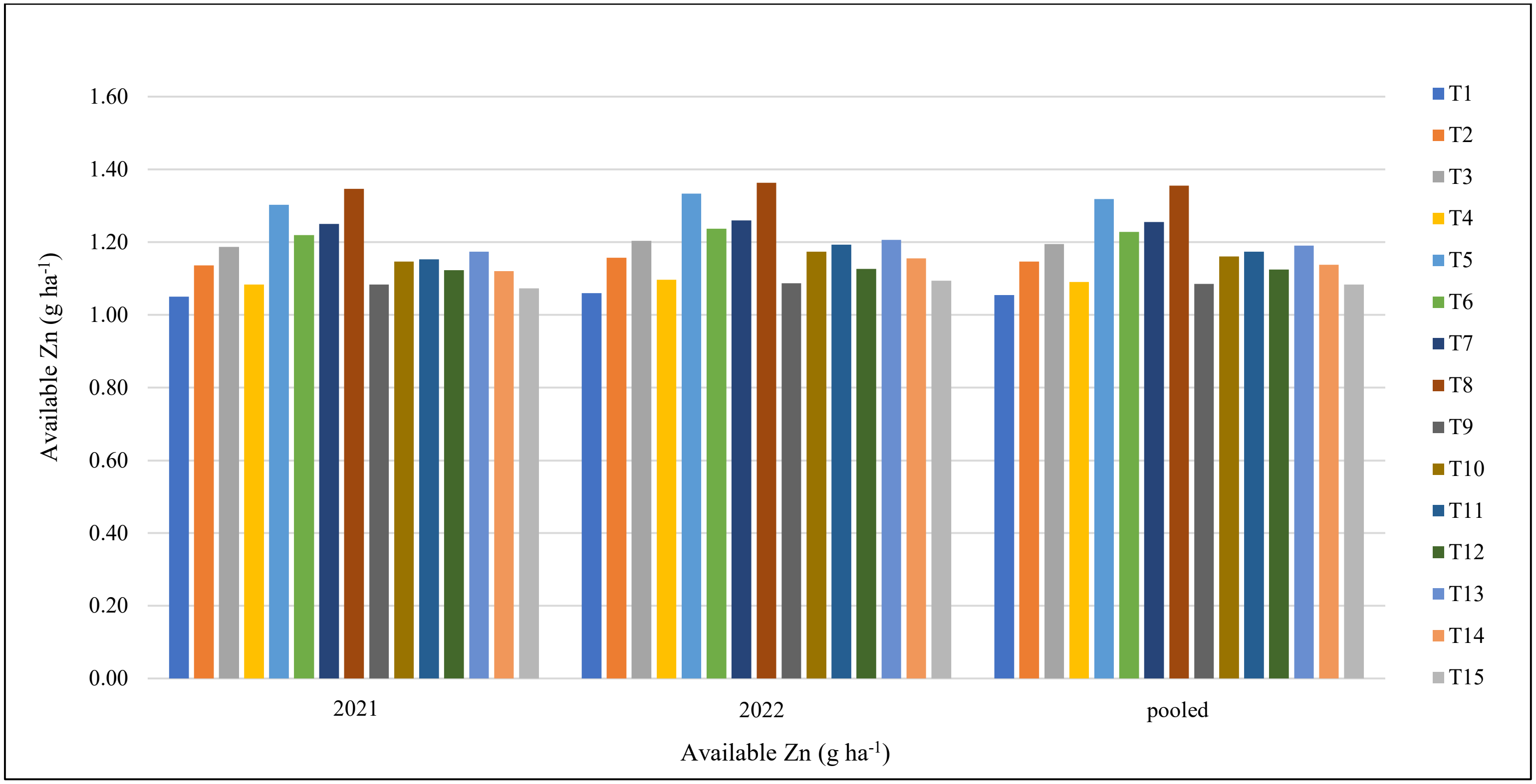


Fig 4.47: Effect of soil fertility management on available Zn (mg ha^{-1}) in direct-seeded rice

Table 4.25: Effect of soil fertility management on available Mn and Cu in direct seeded rice

Treatments	Available Mn (mg kg^{-1})			Available Cu (mg kg^{-1})		
	2021	**2022**	**pooled**	**2021**	**2022**	**pooled**
T_1- Control	12.39	12.41	12.40	1.25	1.27	1.26
T_2- 100% NPK	12.84	12.88	12.86	1.44	1.48	1.46
T_3- 50% NPK	12.76	12.79	12.78	1.36	1.39	1.37
T_4- SSNM (109:30:46 NPK)	13.07	13.11	13.09	1.48	1.51	1.50
T_5- 100% NPK + Zn	12.96	13.00	12.98	1.44	1.46	1.45
T_6- 100% NPK + S	13.25	13.30	13.28	1.54	1.57	1.56
T_7- 100% NPK +Zn + S	13.42	13.44	13.43	1.35	1.37	1.36
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	13.54	13.56	13.55	1.58	1.60	1.59
T_9- 100% NPK + Liming @LR	12.88	12.92	12.90	1.38	1.41	1.39
T_{10}- 50% NPK + Azospirillum	12.84	12.90	12.87	1.44	1.47	1.45
T_{11}- 50% NPK + 50% N-FYM	12.93	12.98	12.95	1.50	1.53	1.51
T_{12}- 50% NPK + 50% N- VC	13.45	13.47	13.46	1.48	1.55	1.52
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	13.43	13.48	13.45	1.57	1.60	1.59
T_{14}- FYM @ 10 t ha^{-1}	13.38	13.42	13.40	1.53	1.55	1.54
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	13.43	13.46	13.45	1.54	1.57	1.56
SEm±	0.53	0.53	0.37	0.11	0.12	0.08
CD(p=0.05)	NS	NS	NS	NS	NS	NS
Initial value	12.48	12.74	-	1.60	1.59	-

4.3.16 Exchangeable acidity [cmol (p+) kg^{-1}]

The results for exchangeable acidity in soil after harvest of crop are revealed in table 4.26 and displayed in fig 4.48.

The pooled data showed that values varied from (T_1) 4.55 to (T_{15}) 2.27 cmol (p^+) kg^{-1} and showed a decline of about 50.11% over control T_1. In T_9 and T_{15}, application of lime was found to have raised the soil pH and reduce acidity by displacement of H^+, Fe^{2+}, Al^{3+} and Mn^{4+} from soil adsorption sites (Osundwa *et al*., 2013). The exchangeable acidity in soil were high at the initial stage as soil had a low pH, acidic but it was observed over the years, the exchangeable acidity gradually decreased with respect to the components of treatments integrated into the soil. Organic manures applied to the soil might have helped in decreasing the soil exchangeable acidity implying the need for organic sources to be applied together with inorganic fertilizers for better soil health and crop development. It was also evident from the results that the value decreased in the second year as compared to the initial year. Critical evaluation of the data show that application of treatments specially the lime treated plots T_9 and T_{15} showed a decline in soil acidity moderately. The decrease might be ascribed to the increase in replacement of Al by Ca in the exchange sites and the subsequent precipitation of Al to Al $(OH)_3$ (Gadisa and Wakgari, 2021). Application of nutrients in an integrated manure like treatments T_8 also recorded a lower acidity value as compared to other treatments as it reduced acidity by 7.47% over control T_1 from the pooled value. Opala *et al*. (2012) who reported that application of FYM increased the soil pH and reduced the soil exchangeable acidity and Al^{3+} in the short term. Ano and Ubochi, (2007) also observed significant change in soil pH from 4.6 to values above 5.6 and exchangeable acidity from 3.00 to below 0.35 cmol (p^+) kg^{-1} due to the application of manure. Application of organic manures results in release of organic acids, which in turn results in decreasing the exchangeable acidity in the soil through chelation. It is these organic anions that consumes protons from the soil thus tending to raise the equilibrium (Haynes and Mokolobate, 2001)

4.3.17 Exchangeable Al^{3+} [cmol (p+) kg^{-1}]

Data pertaining to exchangeable Al^{3+} are represented in table 4.26 and fig 4.49. Results revealed through the pooled data that exchangeable Al^{3+} varied between (T_1) 3.92 to (T_{15}) 1.68 cmol (p^+) kg^{-1} with the treatments under study. Lime treated plots T_9 and T_{15} recorded a decrease in the exchangeable Al^{3+} for both the years which can be attributed to the raise in pH level and subsequently in the decreased of exchangeable Al^{3+} by 54.84% and 57.14% over control T_1, respectively. This may be imputable to the presence of $CaCO_3$ in lime that helped in reducing the soil exchangeable Al^{3+} and raise the pH towards alkalinity. The presence of CO_2^{2-} and OH^- anion in lime neutralizes the H^+ released from the exchange sites and then hydrolysing Al species to the soil solution (Fageria and Baligar, 2008). It was observed that treatments T_8, T_{12}, T_{13} and T_{14} also recorded a slight decline in exchangeable $Al^{3+}$with about 3.63, 3.68, 3.63 and 3.58 cmol (p^+) kg^{-1} respectively as compared to other treatments where it had an integration of organic sources like FYM and vermicompost. As compared to the inorganic fertilizers alone, organic sources proved to have more effect on reducing the soil exchangeable Al^{3+} over both the years of experimentation. Organic sources treated plot showing a decreasing trend in soil exchangeable Al^{3+} can be explained because of the presence of FYM which helped in neutralizing the soil acidic ions. This in conformity with the findings of Fekadu *et al*. (2017) who have reported that addition of organic residues to acid soils can reduce Al toxicity (hence lowering the lime requirement) and enhance P availability. Organic matter reduces Al toxicity and its acidulating effect either by chelating or encapsulating the Al^{3+} (Nyarko, 2012). An increase in soil pH due to manure application apparently resulted in precipitation of exchangeable and soluble Al^{3+} as insoluble Al hydroxides thus reducing the concentration of Al^{3+} in soil solution (Ano and Ubochi, 2007). Another mechanism that has been proposed to explain the increase in soil pH by such material as FYM is specific adsorption of humic material and/or organic acids like oxalic, citric, malic, tartaric, salicylate etc onto hydrous surfaces of Al and Fe oxides by ligand exchange with the corresponding release of OH as suggested by Hue *et al*. (1986).

4.3.18 Total potential acidity [cmol (p+) kg^{-1}]

The data pertaining to total potential acidity in soil after harvest of the crop have been outlined in table 4.27 and depicted in fig 4.50. The total potential acidity in soil value varied from 12.73 and 12.67 cmol (p^+) kg^{-1} for both 2021 and 2022 with pooled value 12.70 cmol (p^+) kg^{-1} in treatment control T_1 to 9.82 and 9.75 cmol (p^+) kg^{-1} for 2021 and 2022 with pooled value 9.78 cmol (p^+) kg^{-1} with treatment T_{15}- FYM @ 10 t ha^{-1} + Liming @LR. Treatment T_9 which also had lime in its treatment combinations similarly observed a decline in total potential acidity with values 9.90 and 9.83 cmol (p^+) kg^{-1} for the year 2021 and 2022 with pooled value 9.87 cmol (p^+) kg^{-1} as compared to the control values. From the pooled data treatments T_9 and T_{15} recorded a decline in acidity to the tune of about 22.28% and 22.99% over control T_1. The declined in the treatment T_9 and T_{15} can be ascribed to the application of lime which had raised pH from an initial acidic condition, by the displacement and replacement of acidic cations like Al^{3+}, H^+ and Fe^{3+} ions by cations Ca^{2+} ions present in the liming material (Kisinyo *et al*., 2013). This is also in conformity with the findings of Ao and Sharma, 2020 who observed that application of lime significantly reduced the total potential acidity of post-harvest soil. Further evaluation of the data showed that addition of organic manures like FYM, vermicompost in the treatments showed a higher total potential acidity of post-harvest soil as compared to treatments that received treatments as gypsum material due to the presence of Ca elements decreased the acidity slightly. Pooled value showed that treatments T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1} (12.27 cmol (p^+) kg^{-1}), T_{10}- 50% NPK + Azospirillum (12.41 cmol (p^+) kg^{-1}), T_{11}- 50% NPK + 50% N-FYM (12.51

cmol (p^+) kg^{-1}), T_{12}- 50% NPK + 50% N- VC (12.44 cmol (p^+) kg^{-1}), T_{13}- 50% NPK + 25% N-FYM + 25% N-VC (12.33 cmol (p^+) kg^{-1}) and T_{14}- FYM @ 10 t ha^{-1} (12.24 cmol (p^+) kg^{-1}) recorded a slight increase in values as compared to other treatments. Application of FYM or any other organic manure to soil led to the contribution of phenolic and carboxylic groups of organic matter towards total potential and pH-dependent acidity and complexing of Al with organic chelates, that also resulted in increased Al^{3+} to some extent as reported by Venkatesh *et al*. 2002. The higher potential acidity may be due to the higher percentage of organic matter in the soil which contributed to total acidity through their functional groups like carboxylic and phenolic hydroxyl groups (Das *et al*. 1991). Debnath *et al*. (2021) reported that correlation coefficient study of soil organic carbon was significantly and positively correlated with pH-dependent acidity and total potential acidity while Kumar *et al*. (1995) reported a negative correlation between pH with total potential acidity and pH dependent acidity.

4.3.19 pH- dependent Acidity [cmol (p+) kg^{-1}]

Results for pH- dependent acidity in soil after harvest of the crop have been laid out in table 4.27. It was observed that pH- dependent acidity value varied between 8.33 and 8.29 cmol (p^+) kg^{-1} (T_{11}) to 7.35 and 7.28 cmol (p^+) kg^{-1} (T_7) for both the years of experimentation 2021 and 2022, respectively. Treatments which received lime T_9 and T_{15} also recorded a lower value of pH-dependent acidity with pooled values 7.48 and 7.52 cmol (p^+) kg^{-1} as compared to the other treatments under study. The reduction in pH- dependent acidity in T_9 and T_{15} was due to the lime application which helped in raising the pH thus reducing the effect of acidity where both the treatments T_{15} and T_9 recorded a decline of about 9.98% and 9.50% over T_{11}, respectively. It was also observed that plots which received sulphur recommended dose showed a lower pH-dependent acidity value for both years 2021 and 2022 such as T_6 - 100% NPK + S (7.37 and 7.35cmol (p^+) kg^{-1}), T_7 - 100% NPK +Zn + S (7.35 and 7.28cmol (p^+) kg^{-1}) except for T_8 - 100% NPK +Zn +S + FYM @ 5t ha^{-1} (8.05 and 8.03

cmol (p^+) kg^{-1}) which had FYM present in the treatment component that recorded a slightly higher value of acidity. The declined in sulphur treated plots could be primarily due to the Ca^{2+} ion present in gypsum which might have helped in stabilizing the acidic ions like H^+ and Al^{3+} present in the soil solution as well as in the soil complexes. Further examination of the data revealed that treatments which received organic manures recorded a higher value in pH-dependent acidity T_{10} (50% NPK + Azospirillum) with 8.10 and 8.11 cmol (p^+) kg^{-1}, T_{12} (50% NPK + 50% N- VC) with 8.22 and 8.14 cmol (p^+) kg^{-1}, T_{13} (50% NPK + 25% N-FYM + 25% N-VC) with 8.02 and 8.04 cmol (p^+) kg^{-1} and T_{14} (FYM @ 10 t ha^{-1}) with 8.12 and 8.09 cmol (p^+) kg^{-1} during the year 2021 and 2022, respectively. During the initial decomposition of manures, formation of phenolic, humic-like material may have occurred (Narambuye and Haynes, 2006). Higher contribution made by organic manures to pH dependent acidity may be due to high content of Fe and Al oxides and organic matter in the soils (Misra *et al*., 1987). Badole *et al*. (2015) reported a positive correlation existed between organic C with pH dependent acidity and total potential acidity in acidic soil of West Bengal while Kumar *et al*. (1995) reported a negative correlation between pH with pH dependent acidity.

The values for pH- dependent acidity in soil failed to show any significant difference among the treatments thus it was proved to be statistically non-significant.

Table 4.26: Effect of soil fertility management on exchangeable acidity and exchangeable Al^{3+} in direct seeded rice

Treatments	Exchangeable acidity [cmol (p^+) kg^{-1}]			Exchangeable Al^{3+} [cmol (p^+) kg^{-1}]		
	2021	2022	pooled	2021	2022	pooled
T_1- Control	4.60	4.50	4.55	4.00	3.83	3.92
T_2- 100% NPK	4.48	4.33	4.41	3.87	3.75	3.81
T_3- 50% NPK	4.52	4.40	4.46	3.80	3.65	3.73
T_4- SSNM (109:30:46 NPK)	4.47	4.33	4.40	3.88	3.67	3.78
T_5- 100% NPK + Zn	4.48	4.45	4.47	3.83	3.67	3.75
T_6- 100% NPK + S	4.33	4.28	4.31	3.83	3.75	3.79
T_7- 100% NPK +Zn + S	4.32	4.23	4.28	3.80	3.72	3.76
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	4.25	4.17	4.21	3.70	3.55	3.63
T_9- 100% NPK + Liming @LR	2.50	2.28	2.39	1.80	1.73	1.77
T_{10}- 50% NPK + Azospirillum	4.38	4.27	4.33	3.77	3.63	3.70
T_{11}- 50% NPK + 50% N-FYM	4.32	4.20	4.26	3.78	3.63	3.71
T_{12}- 50% NPK + 50% N- VC	4.35	4.27	4.31	3.75	3.60	3.68
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	4.33	4.22	4.28	3.73	3.52	3.63
T_{14}- FYM @ 10 t ha^{-1}	4.28	4.23	4.26	3.67	3.50	3.58
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	2.37	2.17	2.27	1.70	1.65	1.68
SEm±	0.07	0.08	0.05	0.14	0.11	0.09
CD(p=0.05)	0.19	0.23	0.15	0.40	0.32	0.25
Initial value	3.83	3.64	-	3.00	2.84	-

Table 4.27: Effect of soil fertility management on total potential acidity and pH-dependent acidity in direct seeded rice

Treatments	Total Potential Acidity [cmol (p^+) kg^{-1}]			pH- dependent acidity [cmol (p^+) kg^{-1}]		
	2021	2022	pooled	2021	2022	pooled
T_1- Control	12.73	12.67	12.70	8.13	7.93	8.03
T_2- 100% NPK	12.57	12.53	12.55	8.08	8.00	8.04
T_3- 50% NPK	12.40	12.32	12.36	7.88	7.85	7.87
T_4- SSNM (109:30:46 NPK)	12.63	12.59	12.61	8.17	8.13	8.15
T_5- 100% NPK + Zn	11.87	11.81	11.84	7.38	7.36	7.37
T_6- 100% NPK + S	11.70	11.63	11.67	7.37	7.35	7.36
T_7- 100% NPK +Zn + S	11.67	11.60	11.63	7.35	7.28	7.32
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	12.30	12.23	12.27	8.05	8.03	8.04
T_9- 100% NPK + Liming @LR	9.90	9.83	9.87	7.40	7.55	7.48
T_{10}- 50% NPK + Azospirillum	12.43	12.38	12.41	8.10	8.11	8.11
T_{11}- 50% NPK + 50% N-FYM	12.53	12.49	12.51	8.33	8.29	8.31
T_{12}- 50% NPK + 50% N- VC	12.47	12.41	12.44	8.22	8.14	8.18
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	12.35	12.30	12.33	8.02	8.04	8.03
T_{14}- FYM @ 10 t ha^{-1}	12.27	12.20	12.24	8.12	8.09	8.10
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	9.82	9.75	9.78	7.45	7.58	7.52
SEm±	0.32	0.38	0.25	0.28	0.43	0.25
CD(p=0.05)	0.93	1.10	0.71	NS	NS	NS
Initial value	12.70	12.60	-	8.87	8.96	-

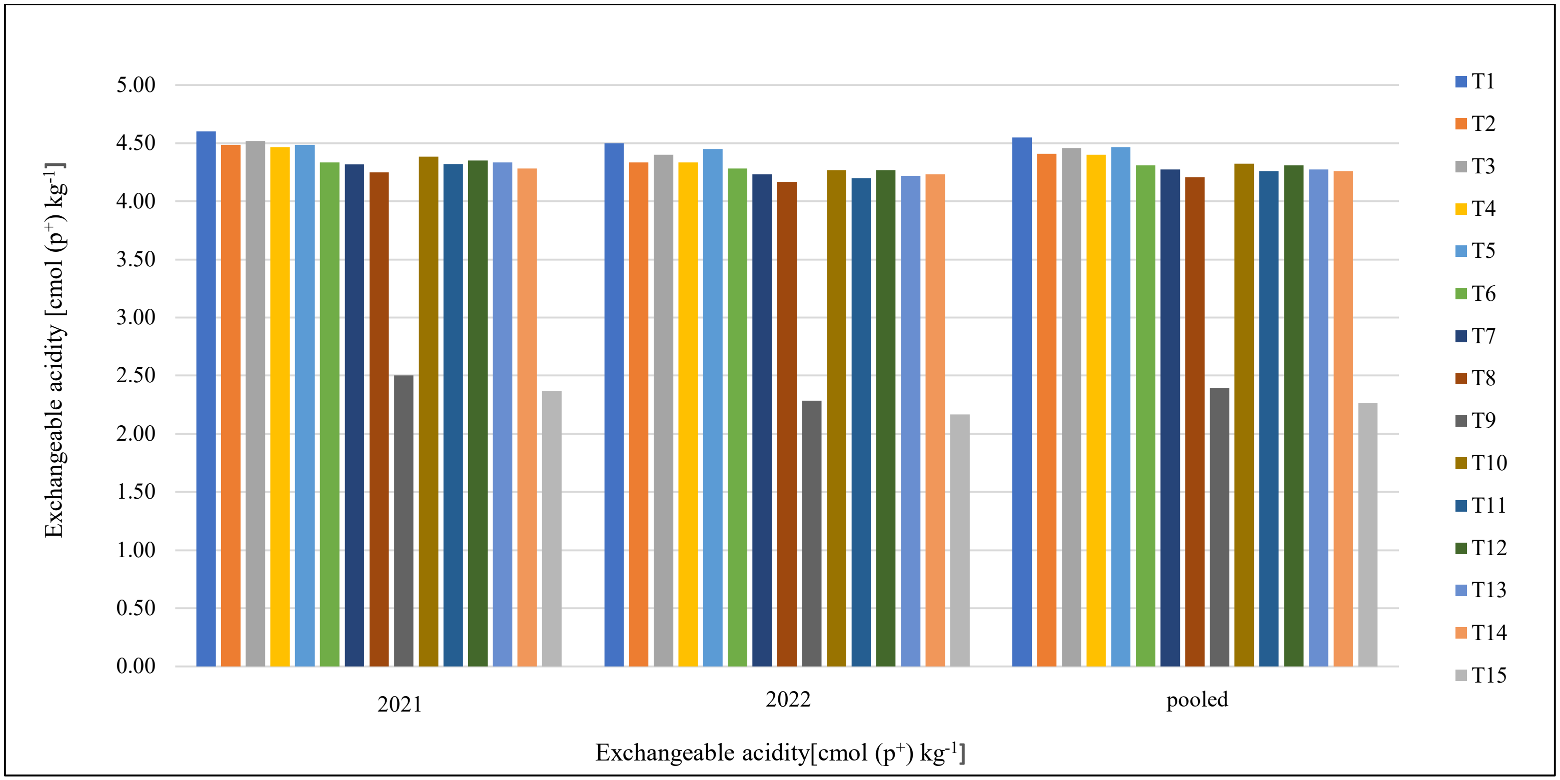


Fig 4.48: Effect of soil fertility management on exchangeable acidity [cmol (p^+) kg^{-1}] in direct-seeded rice

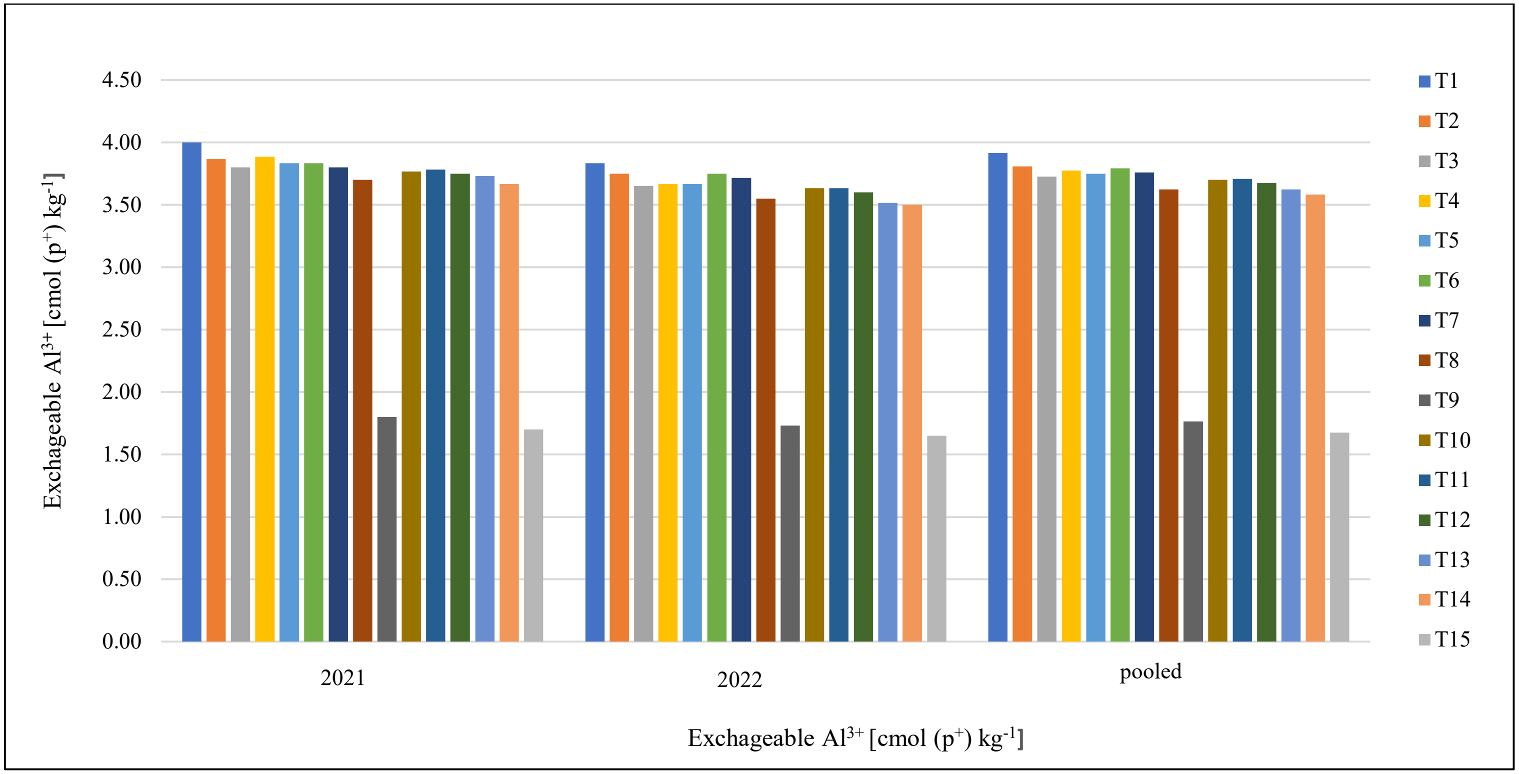


Fig 4.49: Effect of soil fertility management on exchangeable acidity [cmol (p^+) kg^{-1}] in direct-seeded rice

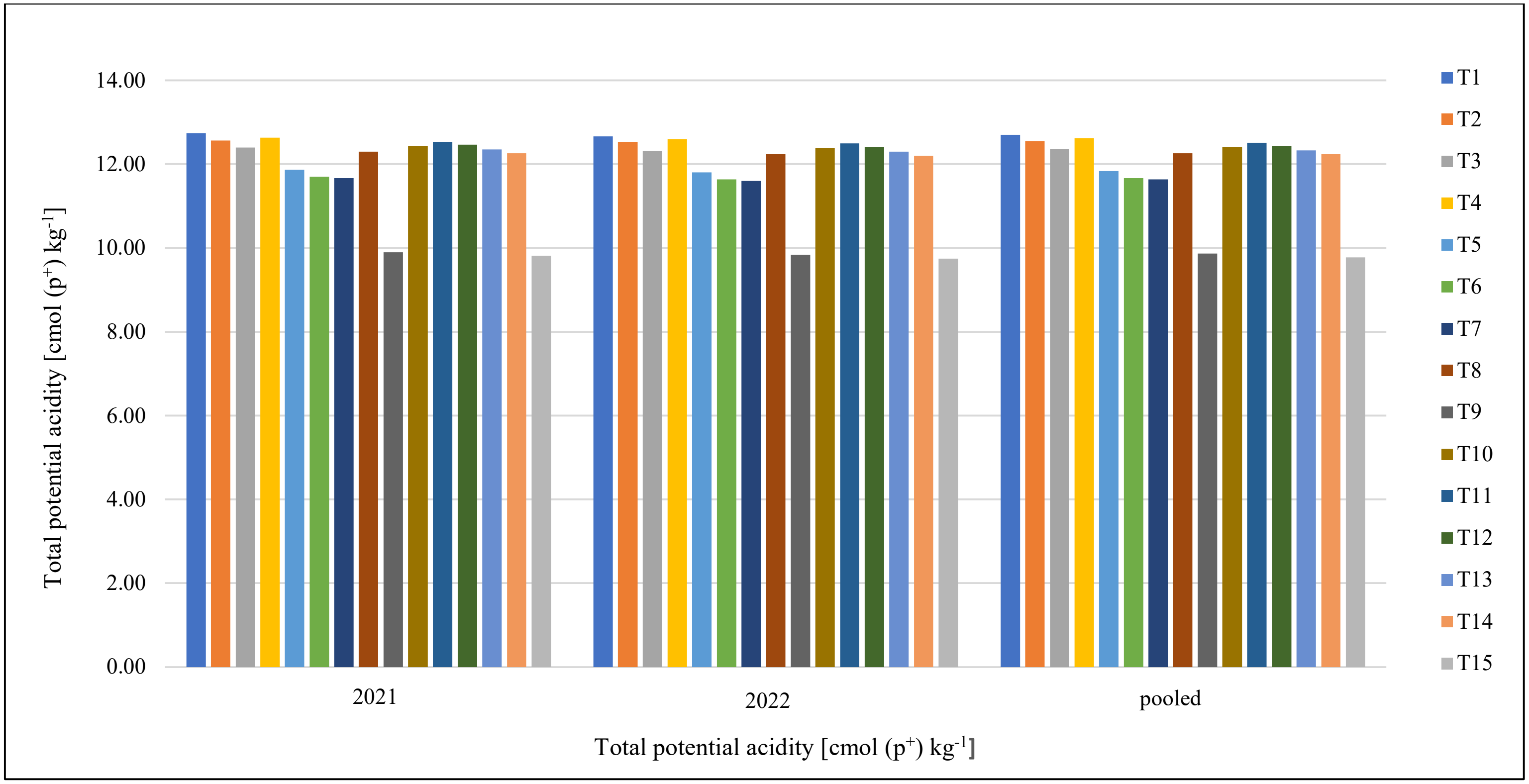


Fig 4.50: Effect of soil fertility management on total potential acidity [cmol (p^+) kg^{-1}] in direct-seeded rice

4.3.20 Soil microbial biomass carbon (µg g^{-1})

The data pertaining to soil microbial biomass carbon after harvest of rice crop are presented in table 4.28 and depicted in fig 4.51. It was clearly observed from the data recorded that integrated application of inorganic fertilizers NPK + S + Zn along with FYM recorded maximum soil microbial biomass carbon as compared to control and other treatments. Treatment T_8 recorded 423.48 and 425.55 µg g^{-1} for the year 2021 and 2022 with a pooled value of 424.52 µg g^{-1} while the minimum was recorded in control T_1 with 161.00 and 163.14 µg g^{-1} for 2021 and 2022 with pooled value 162.07 µg g^{-1} respectively. Further evaluation of the pooled data revealed that T_8 was found to be at par with T_{13} (418.47 µg g^{-1}), T_7 (417.47 µg g^{-1}), and T_{15} (415.23 µg g^{-1}). The soil microbial biomass carbon recorded an increase with the application of T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) to the tune of 161.93% over control T_1, likewise treatments T_{13}, T_7 and T_{15} also recorded an increase of 158.22%, 157.58% and 156.20% over control respectively. Application of T_8 (100% NPK + S + Zn + FYM @ 5 t ha^{-1}) showed a significant increase in the content of SMBC by 74.91% over T_2 - 100% NPK and 1.69% over T_7 (100% NPK + Zn + S) respectively. The higher SMBC recorded in T_8 as compared to T_{14} and T_{15} which had FYM @ 10 t ha^{-1} can be due to the additional readily available nutrients from the fertilizers which improved the growth of the crop with better root growth, biomass, exudates and more plant residues addition after the harvest of the crop thus providing a suitable environment for the microbes to proliferate or another reason may be due to sub optimal quantity of the FYM in T_{14} and T_{15} which failed to reach the favourable microbial environment as satisfied by treatment T_8. Kumari *et al*. (2024) observed that application of organic manures along with NP fertilizers recorded higher microbial biomass which could be the result of the priming effect of applied N. Nitrogen application stimulates the microbial activities which might have led to a commensurate increase in SMBC content during the decay of organic matter. He further reported that $N_{150}P_{30}$ + FYM 15Mg ha^{-1} yr^{-1}

recorded higher microbial carbon which was followed by FYM 15Mg ha^{-1} yr^{-1}. Singh *et al*. (2022) reported that use of FYM alone or in combination with chemical fertilizers significantly increased SMBC as supply of organic manure resulted in higher microbial activity due to additional mineralizable and readily hydrolysable carbon. Similar results were also reported by Kundu *et al*. (2017), Dhiman *et al*. (2019) and Verma *et al*. (2019).

4.3.21 Soil basal respiration (µg CO_2-C g^{-1} h^{-1})

Data for soil basal respiration of the post-harvest soil for both years of experimentation has been illustrated in table 4.28 and graphically depicted in fig 4.52. It was evident form the data obtained that application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) recorded the maximum soil basal respiration value for both years 2021 and 2022 with 13.14 and 13.20 µg CO_2-C g^{-1} h^{-1} and a pooled value of 13.17 µg CO_2-C g^{-1} h^{-1} while the minimum was observed in control T_1 with 9.79 and 9.83 µg CO_2-C g^{-1} h^{-1} for both 2021 and 2022 with a pooled value of 9.81 µg CO_2-C g^{-1} h^{-1} respectively. Treatment T_8 from pooled data recorded an increase of about 34.25% over control T_1 which had no nutrient application in it. Critical examination of the recorded data revealed that T_8 was statistically at par with the application of T_{13} (50% NPK + 25% N-FYM + 25% N-VC) with pooled value 13.13 µg CO_2-C g^{-1} h^{-1} which also gave an increase of about 33.84% over control T_1. Treatment T_{13} was also reported to be at par with T_{15} (FYM @ 10 t ha-1 + Liming @ LR) with value 13.07 µg CO_2-C g^{-1} h^{-1}. Further evaluation revealed that application of T_8 recorded an increase in soil basal respiration about 25.66% over T_2 (100% NPK) and 1.46% over T_{14} (FYM @ 10 t ha^{-1}) elucidating the need for integration of inorganic fertilizers and organic manures for better result. Higher microbial activity as determined by soil basal respiration in treatment T_8 shows that the soil microorganisms were rendered more active. Inorganic fertilizer/supplements exclusively may fulfil the demand for mineral nutrition but not the carbon for cell proliferation of the microorganisms. However, with

Table 4.28: Effect of soil fertility management on soil microbial biomass carbon and soil basal respiration in direct seeded rice

Treatments	SMBC (µg g^{-1})			Soil basal respiration (µg CO_2-C g^{-1} h^{-1})		
	2021	2022	pooled	2021	2022	pooled
T_1- Control	161.00	163.14	162.07	9.79	9.83	9.81
T_2- 100% NPK	241.72	244.81	243.27	10.46	10.49	10.48
T_3- 50% NPK	200.44	206.03	203.24	10.07	10.14	10.10
T_4- SSNM (109:30:46 NPK)	315.61	318.97	317.29	11.51	11.54	11.53
T_5- 100% NPK + Zn	336.96	340.09	338.53	11.62	11.65	11.64
T_6- 100% NPK + S	298.96	304.08	301.52	11.61	11.68	11.65
T_7- 100% NPK +Zn + S	416.17	418.76	417.47	12.58	12.63	12.61
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	423.48	425.55	424.52	13.14	13.20	13.17
T_9- 100% NPK + Liming @LR	346.88	349.34	348.11	12.55	12.64	12.60
T_{10}- 50% NPK + Azospirillum	314.88	317.65	316.27	12.49	12.55	12.52
T_{11}- 50% NPK + 50% N-FYM	341.92	345.68	343.80	12.62	12.66	12.64
T_{12}- 50% NPK + 50% N- VC	371.78	374.19	372.98	12.72	12.76	12.74
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	417.07	419.87	418.47	13.10	13.15	13.13
T_{14}- FYM @ 10 t ha^{-1}	413.75	410.01	411.88	12.95	13.00	12.98
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	414.63	415.84	415.23	13.05	13.08	13.07
SEm±	5.99	5.90	4.20	0.04	0.04	0.03
CD(p=0.05)	17.34	17.09	11.90	0.11	0.12	0.08
Initial value	175.78	216.86	-	9.90	10.17	-

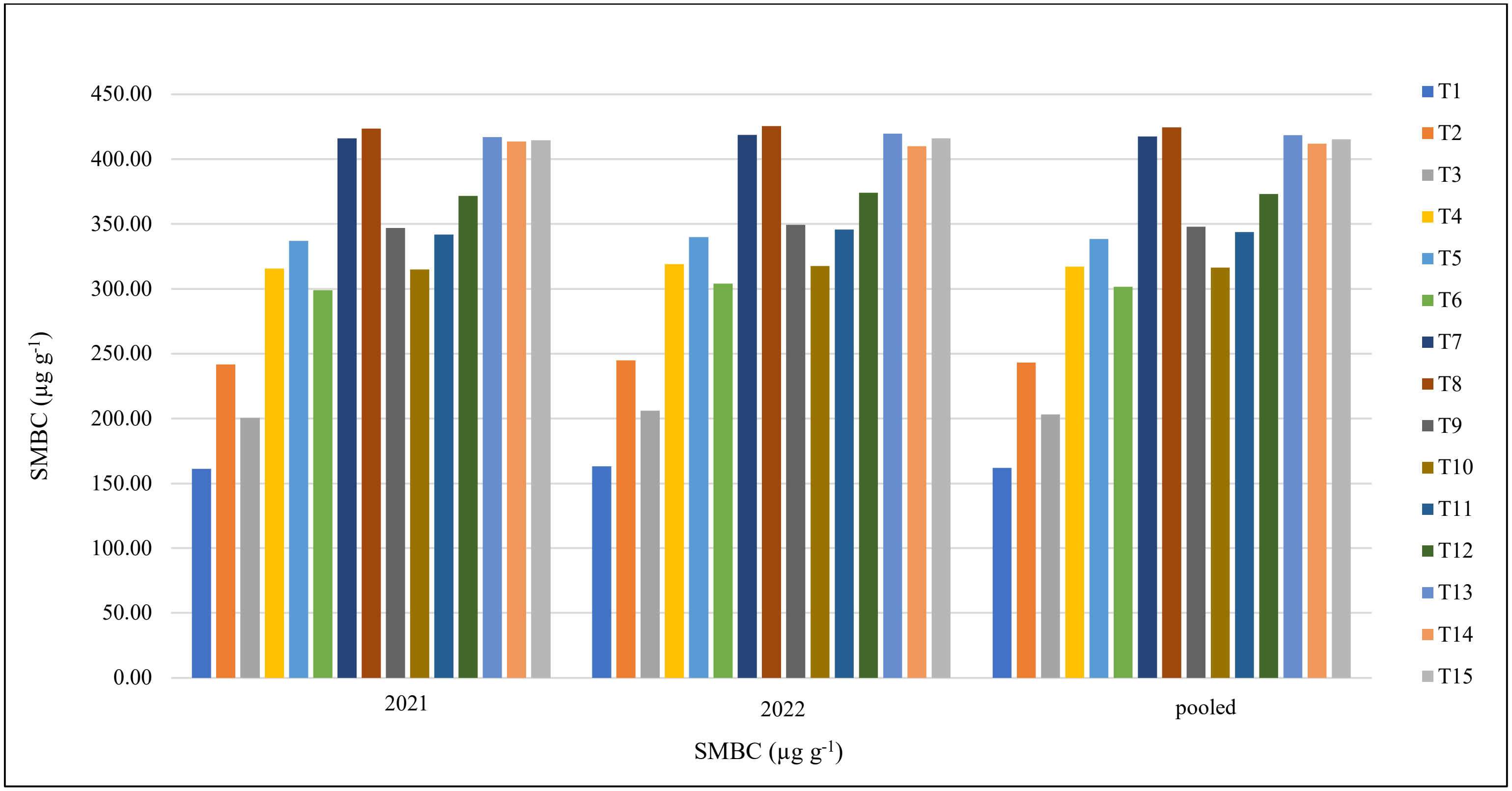


Fig 4.51: Effect of soil fertility management on SMBC (µg g^{-1}) in direct-seeded rice

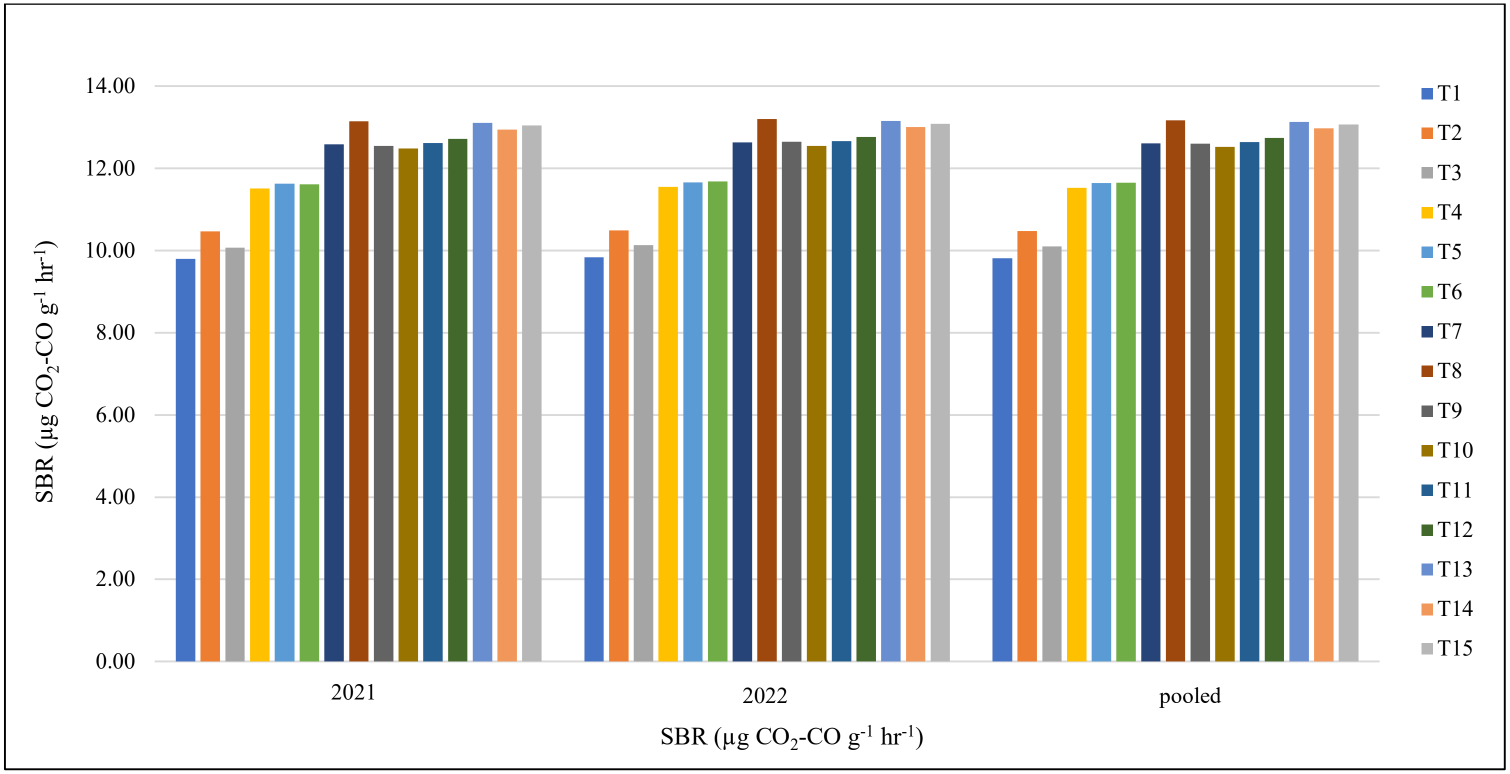


Fig 4.52: Effect of soil fertility management on soil basal respiration (µg CO_2-CO g^{-1} hr^{-1}) in direct-seeded rice

the addition of organic source like FYM/VC that supplied readily available organic matter which in addition led to increasing root biomass and root exudates because of the better crop growth (Kumar *et al*., 2019). N fertilization through chemical fertilizer as well as the additional form FYM supported the enhancement in microbial biomass carbon content, which in turn increased the soil basal respiration rate (Begum *et al*., 2021), which may be due to greater availability and utilization of total organic carbon, either from SOM decomposition or root exudation. The balanced nutrient provided through T_8 and supplementation through FYM may have provided essential energy substrates to support the efficacy of the soil microbial biodiversity, resulting in an increased microbial biomass carbon content of the soil and concomitantly augmented the soil basal respiration.

4.4. Effect of soil fertility management on economics in direct seeded rice.

The data on cost of cultivation, gross return, net return and benefit: cost ratio was calculated using the required formula and has been presented in table 4.29. It was observed that the cost of cultivation was higher in the treatments receiving FYM and vermicompost due to a higher rate as compared to the conventional fertilizer cost and maximum cost was involved with the use of T_{13} (50% NPK + 25% N-FYM + 25% N-VC), followed by T_{12} (50% NPK + 50% N- VC). Sole application of FYM also had higher cost of cultivation as observed in T_{14} (FYM @ 10 t ha^{-1}) and T_{15} (FYM @ 10 t ha^{-1} + Liming @ LR) which had an additional cost due to the liming material. In treatments like control T_1, T_3 (50% NPK), T_{10} (50% NPK + Azospirillum) were found to have incurred a lesser cost of cultivation as in case of control (T_1) no fertilizer application was carried out therefore fertilizers cost was not included in the cost of cultivation, while in T_3, cost of fertilizers was lesser as the application of NPK was at the rate of 50% as compared to full dose of fertilizer (100% NPK) while for T_{10}, cost of biofertilizers Azospirillum were comparatively cheaper than FYM and Vermicompost. Similar observations were also noted by Rama *et al*. (2020) and

Mandal *et al*. (2018). Highest gross return was recorded when the crop was supplied with sufficient nutrients as observed in T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) for both the years 2021and 2022 that gave a return of about 115782.26 ₹ ha^{-1} and 120040.13 ₹ ha^{-1}, respectively. This was followed by the application of T_7 (100% NPK +Zn + S) with gross return for both the years, 107348.10 ₹ ha^{-1} and 111902.66 ₹ ha^{-1} and T_{13} (50% NPK + 25% N-FYM + 25% N-VC) with return values of 103043.46 ₹ ha^{-1} and 108447.33 ₹ ha^{-1}. The highest net returns for both the years of experimentation were recorded with the application of T_7 (100% NPK +Zn + S) with a net return value of 66710.72 ₹ ha^{-1} and 71265.29 ₹ ha^{-1} followed by T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) with 65145.26 ₹ ha^{-1} and 69403.13 ₹ ha^{-1}, respectively. It was evident that control treatment recorded the least gross and net returns during both the years of experimentation. Similar results were reported from Tiwari *et al*. (2017) and Singh *et al*. (2019). The benefit: cost ratio was found highest in T_7 (100% NPK +Zn + S) with 1.64 and 1.75 followed by T_4 (SSNM (109:30:46 NPK) with 1.63 and 1.71, T_5 (100% NPK +Zn +S) with 1.50 and 1.57, T_{10} (50% NPK + Azospirillum) with 1.33 and 1.45, and T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) with 1.29 and 1.37 for both the years of experimentation 2021 and 2022, respectively. The higher B: C ratio in the sole fertilizer application might have been due to the lesser cost of fertilizer as compared to the treatment T_8 which had fertilizers and an addition of FYM, however both the gross and net returns were found to be higher with T_8 as this treatment provided a balanced form of nutrients both chemically and organically resulting to a higher crop biological and economical yields. Several researchers have also noted variation in economics of rice crop due to nutrient management treatments (Rama *et al*., 2020 and Baishya *et al*., 2015).

Table 4.29: Effect of soil fertility management on economics in direct seeded rice

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})		Net return (₹ ha^{-1})		B: C Ratio	
		2021	2022	2021	2022	2021	2022
T_1- Control	31019.00	55159.26	56487.06	24140.26	25468.07	0.77	0.82
T_2- 100% NPK	36649.13	80474.70	81224.46	43825.57	44575.34	1.19	1.21
T_3- 50% NPK	33834.07	74415.06	76798.13	40580.99	42964.06	1.20	1.26
T_4- SSNM (109:30:46 NPK)	34837.60	91929.86	94485.16	57092.26	59647.57	1.63	1.71
T_5- 100% NPK + Zn	39409.93	98764.10	101352.00	59354.17	61942.07	1.50	1.57
T_6- 100% NPK + S	38262.08	87412.66	89858.90	49150.58	51596.82	1.28	1.34
T_7- 100% NPK +Zn + S	40637.38	107348.10	111902.66	66710.72	71265.29	1.64	1.75
T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1}	50637.00	115782.26	120040.13	65145.26	69403.13	1.29	1.37
T_9- 100% NPK + Liming @LR	42271.80	95205.83	98220.33	52934.03	55948.53	1.25	1.32
T_{10}- 50% NPK + Azospirillum	33858.08	79200.00	82971.00	45341.92	49112.92	1.33	1.45
T_{11}- 50% NPK + 50% N-FYM	53834.08	89898.00	93633.23	36063.92	39799.15	0.67	0.73
T_{12}- 50% NPK + 50% N- VC	75500.58	84473.06	88451.83	8972.48	12951.25	0.12	0.17
T_{13}- 50% NPK + 25% N-FYM + 25% N-VC	84667.33	103043.46	108447.33	18376.13	23780.00	0.21	0.28
T_{14}- FYM @ 10 t ha^{-1}	51019.00	84119.23	86564.20	33100.23	35545.20	0.64	0.69
T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR	56641.70	79603.20	83399.20	22961.50	26757.50	0.41	0.47

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

A research investigation title "Soil fertility management under direct seeded rice (*Oryza sativa* L.) in the acidic soil of Nagaland" was conducted during the *kharif* season of 2021 and 2022 at the experimental farm of the Department of Soil Science, School of Agricultural Sciences (SAS), Nagaland University, Medziphema, Nagaland. The main findings of the investigations are summarized as below:

A. Effect of soil fertility management on growth in direct seeded rice

The growth attributing parameters were recorded in term of plant height (45, 90 DAS and at harvest), number of tillers m^{-2}, crop growth rate and relative growth rate at 45 and 90 DAS respectively.

1. Application of RDF 100% NPK+ Zn +S + FYM @ 5 t ha^{-1} significantly enhanced the plant height at different growth stages. Plant height at 45, 90 DAS and at harvest recorded pooled value of 72.08 cm, 111.41 cm, 134.46 cm, respectively with T_8 treatment (100% NPK +Zn +S + FYM @ 5t ha^{-1}) significantly highest among the other treatments. The lowest was recorded in the control plot with pooled values 43.61 cm, 70.23 cm and 86.01 cm, respectively. The data pertaining to plant height showed that it was significantly influenced due to the soil fertility management practices at different stages of the plant growth.
2. Number of tillers $plant^{-1}$ at 45 and 90 DAS were also recorded to be significantly enhanced and increased by the treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}). The highest pooled values were recorded with T_8 (5.57 and 7.63) as compared to control T_1 (3.30 and 4.57) at 45 and 90 DAS in both years, respectively which was found to be significant. Minimum tiller $plant^{-1}$ were recorded with the control (T_1) which had no nutrient application.

3. Crop growth rate (CGR) of rice crop at 45 and 90 DAS were also significantly enhanced among the treatments according to the different integrated nutrients applied. Treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) was recorded to be highest among all the treatments in both years 2021 and 2022 with (3.70 and 4.02 g m^{-2} day^{-1}) and (7.07 and 7.06 g m^{-2} day^{-1}) as compared to control T_1 (2.18 and 2.29 g m^{-2} day^{-1}) (5.05 and 5.14 g m^{-2} day^{-1}), respectively. The pooled data recorded the highest value with T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) 3.86 and 7.07 g m^{-2} day^{-1} while the lowest value in control T_1 with 2.24 and 5.09 g m^{-2} day^{-1} for both the stages of growth, respectively.
4. Relative growth rate (RGR) at 0-45 DAS of the crop were also found to have significant effect in the year 2021 and 2022 with value 0.027 and 0.029 g g^{-1} day^{-1} with T_8 while the control recorded the lowest with 0.02 and 0.03 g g^{-1} day^{-1}, respectively. The values of RGR during 45-90 DAS varied between 0.03 to 0.04 g g^{-1} day^{-1} where the lowest was recorded with control T_1 and the treatments which received nutrients whether from inorganic or organic source all recorded a similar value.

B. Effect of soil fertility management on yield in direct seeded rice

The yield parameters that were recorded are Number of panicle m^{-2}, Length of panicle (cm), Number of grains $panicle^{-1}$, Number of filled grains $panicle^{-1}$, Number of unfilled grains $panicle^{-1}$, Test weight (g), Grain yield (kg ha^{-1}), Straw yield (kg ha^{-1}) and Harvest Index (%), respectively.

1. Length of panicle (cm) values varied from (29.67, 31.00) to (16.67, 17.67) for both years 2021 and 2022 where T_8 proved to be significantly higher than all treatments and control recorded the lowest while the pooled data also varied from 26.15 cm to 27.68 cm. However, the treatments under study could show any significant difference and therefore remained non-significant.

2. Number of panicle m^{-2} was found to vary from 16.67 and 17.67 to 29.67 and 31.00 for both the years of experimentation, respectively where T_8 was able to record significantly the highest and control T_1 with the least number of panicles m^{-2}. It was observed that T_8 recorded an increase of about 76.64% from the pooled value over control T_1 and 22.94% increase over T_2 - 100% NPK alone.
3. Number of grains panicle^{-1} data showed highest with T_8 treatment (100% NPK +Zn +S + FYM @ 5t ha^{-1}) with the pooled value of 127.73 and lowest in control T_1 with 89.53. Treatment T_8 proved to be significantly higher than all the other treatments followed by T_7 (100% NPK +Zn + S) with value of 121.13. It was observed that application of T_8 recorded an increase of about 42.66% over control T_1.
4. The highest number of filled grains panicle^{-1} was recorded with T_8 treatment (100% NPK +Zn +S + FYM @ 5t ha^{-1}) with pooled value of 120.80 while lowest observed with T_1 with a pooled value of 80.63. The highest number of unfilled grains panicle^{-1} was recorded in T_1 (8.90) while T_8 (3.77) recorded the lowest among all the treatments.
5. Test weight (g) was recorded highest in T_8 with the pooled value of 25.40 g as compared to control T_1 with a value of 24.43 g. However, all the treatments failed to show any significant variation during both the years of experimentation.
6. Grain yield (kg ha^{-1}) of rice crop increased significantly with T_8 treatment (100% NPK +Zn +S + FYM @ 5t ha^{-1}) during both the years of experimentation. T_8 proved to be significantly highest with the value of 4767.87 kg ha^{-1} and 4939.60 kg ha^{-1} during 2021 and 2022, respectively with the pooled value 4853.73 kg ha^{-1} while the lowest in T_1 with value 2212.87 and 2264.80 kg ha^{-1} during 2021 and 2022 with a pooled value of 2238.83 kg ha^{-1} respectively. Treatment T_8 increased the grain yield to the extent of 115.46% and 117.81 % during the first and second year of

experimentation with pooled value of 116.79% over control T_1, respectively.

7. Straw yield (kg ha^{-1}) were also found to have significant results where T_8 treatment (100% NPK +Zn +S + FYM @ 5t ha^{-1}) proved to be significantly highest with value of 6121.33 kg ha^{-1} and 6429.33 kg ha^{-1} for the year 2021 and 2022, respectively with pooled value of 6275.33 kg ha^{-1} as compared to all the other treatments while the lowest was observed in control T_1 with 4263.33 kg ha^{-1} and 4396.67 kg ha^{-1} in 2021 and 2022, respectively with pooled value of 4330.00 kg ha^{-1}. Application of T_8 treatment (100% NPK +Zn +S + FYM @ 5t ha^{-1}) enhanced the stover yield by 43.58% and 46.23% over control during first and second year of experimentation, respectively while pooled straw yield enhanced to the extent of 44.92% over control as well.
8. Harvest Index (%) was also recorded highest in T_8 with 43.57 % and lowest with control T_1 (32.97 %). In pooled value of HI (%), T_8 was proved to be significantly at par with T_7 (100% NPK +Zn +S) with a value of 43.00%.

C. Effect of soil fertility management on nutrient content, uptake and total uptake in direct seeded rice

1. The effect of different treatments under study indicated that nitrogen content in grain ranged from 0.92 % to 1.19 % in 2021 and 0.93 % to 1.20 % in 2022, where treatment T_8 recorded the highest among all the treatments and T_1 recording the lowest, respectively. Pooled value also revealedT_8 obtained the highest content (1.19%) and lowest with T_1 (0.93%). Further evaluation shows that T_8 increased to an extend of 29.24% and 29.03% over the control in the year 2021 and 2022, respectively.
2. Treatment T_8 significantly increased the plant grain phosphorus content in both years 2021 and 2022 with values of 0.29% and 0.31% with pooled

value of 0.30% while the lowest was recorded in control plot for the year 2021 and 2022 with values 0.15% and 0.18% and pooled value of 0.16%, respectively. P content in grain was found to have increased by 87.5% over control with application of treatment T_8. Similarly, phosphorus content in straw was highest in T_8 with 0.90% and 0.90% for 2021 and 2022 with a pooled value of 0.90% while the lowest in control plot with 0.06% and 0.07% and pooled value of 0.07% for 2021 and 2022, respectively. In the year 2022, the straw content of phosphorus in treatment T_8 was recorded at par with treatment T_7 while remaining significantly highest over all the other treatments. Further evaluation of pooled data indicated that P content in straw increased to an extent of 28.57% over control.

3. The effect of different treatments on potassium content in grain and straw revealed that T_8 recorded highest with 0.44% for the year 2021 and 0.45% for the year 2022 with pooled value of 0.41% while the lowest was in T_1 with 0.30% for 2021 and 0.31% for 2022 with pooled value of 0.30%, respectively. From the pooled data it was observed that with the application of T_8, potassium content in grain increased by 36.66% over control. It was also critically observed that T_8 remained at parity with T_5 (0.42%), T_7 (0.42%) and T_{13} (0.42%). While maximum potassium content in straw was recorded with treatment T_8 with 1.32% and 1.33% for 2021 and 2022 with pooled value of 1.33%, respectively conversely the minimum was recorded in control T_1 with 1.03% and 1.05% for 2021 and 2022, respectively with a pooled value of 1.04%.
4. This study revealed that maximum sulphur content in grain was recorded in treatment T_7 and T_8 both with 0.47% for the year 2021 and at par to T_5 with 0.45%. While in 2022, treatment T_8 recorded highest 0.49% and reported to be at par with T_7 (0.48%) while lowest was recorded in control T_1 with value of 0.26%. Further evaluation shows that T_7 at par with T_5

and T_6 both with a sulphur content of 0.46%. It was observed that in the pooled data that sulphur treated plots recorded higher content than other treatments, with T_7 and T_8 recording the highest with a value of 0.48%. Meanwhile the highest sulphur content in straw was recorded in treatment T_8 with 0.23% in 2021 and 0.24% in 2022 with pooled value of 0.24% while the lowest was recorded in control T_1 with a value of 0.16% and 0.17% for both the years and pooled value 0.16%, respectively. Further evaluation of the pooled data revealed that treatment T_8 was statistically at par with T_6, T_7, T_9, T_{11} and T_{12}.

5. A critical examination of the pooled data revealed that calcium content in grain increased from 0.06% to 0.09%. Application of treatment T_8 improved the calcium content in grain to the extent of 50% over control T_1. On the other hand, pooled value of calcium content in straw showed that calcium content increased from 0.98% to 1.06% where lowest was recorded in control T_1 and highest was observed from the lime treated plot T_{13}. However, the different treatments under study could not show any significant difference.
6. Micronutrients Zn, Fe, Mn and Cu content in seed and straw of the crop were found to have been enhanced by the different treatments under study, however significant difference among them was not observed. Although the values were observed to have slightly increased in both grain and straw with Zn content ranging from 27.56-30.42 mg kg^{-1} in grain and 39.86-44.48 mg kg^{-1} in straw, Fe content ranging from 57.31-58.59 mg kg^{-1} in grain and 93.08-97.33 mg kg^{-1} in straw, Mn content ranging from 42.20-49.92 mg kg^{-1} in grain and 63.30-66.97 mg kg^{-1} in straw) and Cu content ranging from 5.00-7.88 mg kg^{-1} in grain and 7.90-11.34 mg kg^{-1} in straw, respectively. The highest micronutrients content in both grain and straw was observed in T_8 while the lowest was observed in control T_1, with the exception of T_3 which recorded the lowest Cu content in straw.

7. The treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) significantly influenced the N, P, K, S, Ca, S and micronutrient (Zn, Fe, Mn, Cu) uptake and total uptake over all other treatments under study during both 2021 and 2022.

D. Effect of soil fertility management on soil properties in direct seeded rice

1. The different treatments under study did not have any significant effect on the soil EC (dSm^{-1}) and bulk density (g cm^{-3}). However, it was observed that soil pH recorded a slight increase from 4.50 to 5.96 in the pooled data where lime treated plots T_9 and T_{15} increased, EC also varied between 0.03 to 0.04 dSm^{-1}, while the bulk density of the soil decreased from 1.45 to 1.41 g cm^{-3} especially due to the addition of FYM which help in soil aggregation.
2. Organic carbon (g kg^{-1}), total organic carbon (g kg^{-1}) was also found to have recorded higher with the application of T_8 as it increased the organic carbon by 30.24% over control T_1. Maximum organic carbon was recorded under T_8 (18.93 and 18.97 g kg^{-1}) with pooled value of 18.95 g kg^{-1} while the minimum was recorded in T_1 (14.43 and 14.67g kg^{-1}) with pooled value of 14.55 g kg^{-1}. Similarly, T_8 (26.30 and 26.50 g kg^{-1}) recorded the highest total organic carbon with pooled value of 26.40 g kg^{-1} while the lowest total organic carbon was recorded with control T_1 (22.03 and 22.18 g kg^{-1}) with pooled value of 22.11 g kg^{-1}. As T_8 had an integration of both inorganic fertilizers and organic manures, it improves the soil condition which resulted in a higher yield of the crop rendering more crop residues to return to the soil for further decomposition. Otherwise in CEC, higher value was recorded in T_{15} (14.27 and 14.35 cmol (p^+) kg^{-1}) due to the addition of FYM along with lime as both the elements play an important in soil aggregation enhancing the physico-chemical property of the soil. This was followed by treatments which had organic manure application in the soil with T_8 (13.50 and 13.53 cmol (p^+)

kg^{-1}), T_9 (13.19 and 13.23 cmol (p^+) kg^{-1}), T_{11} (13.67 and 13.71 cmol (p^+) kg^{-1}), T_{13} (13.99 and 14.04 cmol (p^+) kg^{-1}), and T_{14} (14.12 and 14.20 cmol (p^+) kg^{-1}), respectively for both the years of experimentation.

3. Available N, P and K in soil was observed to be significantly increased with the application of T_8 which recorded the highest available N content of 285.12 and 287.26 kg ha^{-1} with pooled value of 286.19 kg ha^{-1}, available P content of 18.15 and 18.22 kg ha^{-1} with pooled value of 18.18 kg ha^{-1}, available K content of 116.27 and 117.93 kg ha^{-1} with pooled value of 117.10 kg ha^{-1} in 2021 and 2022, respectively. The control T_1 recorded the lowest available N content of 243.32 and 248.24 kg ha^{-1} with pooled value of 245.78 kg ha^{-1}, available P content of 8.22 and 8.34 kg ha^{-1} with pooled value of 8.28kg ha^{-1} and available K content of 96.13 and 96.40 kg ha^{-1} with pooled value of 96.27 kg ha^{-1} in 2021 and 2022, respectively. The pooled data revealed an increase of available NPK of about 16.70%, 119.56% and 21.63%, respectively over control T_1 with the with application of T_8.
4. Secondary nutrients like available S and exchangeable Ca were observed to have been influenced by the different treatments under study. Available sulphur was reported maximum in T_8 (15.70 and 15.72 kg ha^{-1}) while minimum in control T_1 (13.19 and 13.21 kg ha^{-1}). Sulphur treated plots T_7 (15.67 and 15.70 kg ha^{-1}), T_6 (15.56 and 15.61 kg ha^{-1}) and T_5 (15.42 and 15.45 kg ha^{-1}) also recorded a higher value compared to other treatments. Exchangeable Ca was recorded highest in the treatment T_9 with the value of 1.25 cmol (p^+) kg^{-1}for the year 2021 while T_{15} recorded the highest value with1.26 cmol (p^+) kg^{-1} for the year 2022 and the lowest was observed from the control T_1 with 1.16 cmol (p^+) kg^{-1} and 1.17 cmol (p^+) kg^{-1} for both the years of experimentation, respectively. However, exchangeable Ca was not found to be significant.

5. Micronutrients like Zn, Fe, Mn and Cu were also observed to be highest with the application of T_8. Available Zn with T_8 was highest (1.35 and 1.36 kg ha^{-1}) while the lowest was recorded with the control treatment T_1 (1.05 and 1.06 kg ha^{-1}) where it recorded an increase in soil available zinc of about 28.30% over control T_1. Data recorded revealed that available iron in soil ranged from 32.78 mg kg^{-1} and 32.75 mg kg^{-1} to 33.97 mg kg^{-1} and 33.74 mg kg^{-1} for both the years 2021 and 2022, respectively. Available manganese recorded an increase with the application of different treatments over the years as the values varied from 12.39 mg kg^{-1} to 13.54 mg kg^{-1} for the year 2021 and 12.41 mg kg^{-1} to 13.56 mg kg^{-1} for the year 2022 with treatment control T_1 and T_8, respectively. Pooled value discloses that available manganese increased to an extend of about (T_8) 9.26% over control (T_1). Available copper in soil was also found to have increased over both the years of experimentation as values varied from (T_1) 1.25 and 1.27 mg kg^{-1} to (T_8) 1.58 and 1.60 mg kg^{-1}. However, available Fe, Mn and Cu among different treatments did not show any significant difference.
6. Acidity parameters like exchangeable acidity, exchangeable Al^{3+}, TPA and pH-dependent acidity were observed to have decreased with the application of different treatments as compared to control. Lime treated plots recorded a more decline in exchange acidity as values varied from (T_1) 4.55 to (T_{15}) 2.27 cmol (p^+) kg^{-1} and showed a decline of about 50.11% over control T_1. Application of nutrients in an integrated manure like treatments T_8 also recorded a lower acidity value as compared to other treatments as it reduced acidity by 7.47% over control T_1 from the pooled value. Results revealed through the pooled data that exchangeable Al^{3+} varied between (T_1) 3.92 to (T_{15}) 1.68 cmol (p^+) kg^{-1} with the treatments under study. Lime treated plots T_9 and T_{15} recorded a decrease in the exchangeable Al^{3+} for both the years which can be attributed to the

raise in pH level and subsequently in the decreased of exchangeable Al^{3+} by 54.84% and 57.14% over control T_1, respectively. It was observed that treatments T_8, T_{12}, T_{13} and T_{14} also recorded a slight decline in exchangeable $Al^{3+}$with about 3.63, 3.68, 3.63 and 3.58 cmol (p^+) kg^{-1} respectively as compared to other treatments where it had an integration of organic sources like FYM and vermicompost. The total potential acidity in soil value varied from 12.73 and 12.67 cmol (p^+) kg^{-1} for both 2021 and 2022 with pooled value 12.70 cmol (p^+) kg^{-1} in treatment control T_1 to 9.82 and 9.75 cmol (p^+) kg^{-1} for 2021 and 2022 with pooled value 9.78 cmol (p^+) kg^{-1} with treatment T_{15}- FYM @ 10 t ha^{-1} + Liming @LR. Treatment T_9 which also had lime in its treatment combinations similarly observed a decline in total potential acidity with values 9.90 and 9.83 cmol (p^+) kg^{-1} for the year 2021 and 2022 with pooled value 9.87 cmol (p^+) kg^{-1} as compared to the control values. From the pooled data treatments T_9 and T_{15} recorded a decline in acidity to the tune of about 22.28% and 22.99% over control T_1. pH – dependent values were found to be non-significant over both he years of experimentation.

7. Soil microbial biomass carbon and soil basal respiration were found to be significantly enhanced by the application of different treatments under study where T_8 recorded the highest for both the parameters. The soil microbial biomass carbon recorded an increase of 161.93% over control with the application of T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}), likewise treatments T_{13}, T_7 and T_{15} also recorded an increase of 158.22%, 157.58% and 156.20% over control, respectively. Treatment T_8 from pooled data recorded an increase of soil basal respiration with about 34.25% over control T_1.

E. Effect of soil fertility management on economics in direct seeded rice

The economics of the different treatments under study revealed that cost of cultivation was highest in T_{13}- 50% NPK + 25% N-FYM + 25% N-

VC, followed by T_{12}- 50% NPK + 50% N- VC. Sole application of FYM also had higher cost of cultivation as observed in T_{14}- FYM @ 10 t ha^{-1} and T_{15}- FYM @ 10 t ha^{-1} + Liming @ LR. Highest gross return was recorded when the crop was supplied with sufficient nutrients as observed in T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) for both the years 2021and 2022 that gave a return of about 115782.26 ₹ ha^{-1} and 120040.13 ₹ ha^{-1}, respectively while the lowest gross and net returns were incurred from the control T_1. However, net returns were recorded highest from T_7 with 66710.72 ₹ ha^{-1} and 71265.29 ₹ ha^{-1} and followed by T_8 with a net return of 65145.26 ₹ ha^{-1} and 69403.13₹ ha^{-1}, respectively for both the years. Treatments variation was observed in this study as treatments B:C ratios for T_7- 100% NPK +Zn + S (1.64 and 1.75) recorded the highest followed by T_4- SSNM (109:30:46 NPK) (1.63 and 1.71), T_5- 100% NPK +Zn (1.50 and 1.57), T_{10}- 50% NPK +Azospirillum (1.33 and 1.45) and T_8- 100% NPK +Zn +S + FYM @ 5t ha^{-1} (3.51 and 3.67). The higher B:C ratio of T_7 as compared to T_8 was due to the additional FYM that was incorporated as compared to T_7 which had sole fertilizer application.

CONCLUSION

From the present investigation, it can be concluded that application of 100% NPK +Zn +S + FYM @ 5t ha^{-1} performed significantly superior to other treatments in terms of the crop growth attributes, yield, nutrient concentration and their uptake during both the years of experimentation. Combined application of inorganic fertilizers and organic sources of nutrients for soil fertility management not only promoted the crop overall development but it also enhanced the nutrient availability in soil by improving soil cation exchange capacity, soil organic carbon and total organic carbon while lowering bulk density of the soil. Available macronutrients both primary and secondary nutrients like N, P, K, S and Ca were also found to have increased over the years of investigation. Micronutrients like Zn, Fe, Mn and Cu were also found to be higher with the application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) than the other treatments. Soil acidity parameters such as exchange acidity, exchangeable Al^{3+}, total potential acidity and pH-dependent acidity were also observed to have slightly decreased over control. T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) also improved the soil biological parameters like soil microbial biomass carbon and soil basal respiration and significantly outperformed the other treatments under study. As observed from the outcome of the present investigation, some variations in the B:C ratio was observed due to the different components of the treatments. However, the economics of application of treatment T_8 (100% NPK +Zn +S + FYM @ 5t ha^{-1}) was observed to be most beneficial which recorded the highest gross and net return among all other treatments.

Thus, for the sustenance of soil health and productivity in the long run and furthermore not compromising as well as disregarding the importance of growth and yield of the crop, supplying of the available nutrients to soil through inorganic fertilizers and subsequently with the slow decomposition nature of organic manures at the later stages of the crop growth, the application of 100% NPK +Zn +S + FYM @ 5t ha^{-1} was observed to be a suitable soil fertility management practice in direct seeded rice on the acidic soil of Nagaland through the two years experimentation. In the economics point of view as well, treatment T_8 was shown to have a higher gross and net returns as compared to others which could possibly help the farmers to generate revenues from their produce with minimal burdens on the cost of inputs and cultivation.

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APPENDICES

Appendix – A

ANOVA – I (a): Analysis of variance for effect of soil fertility management on plant height at 45 DAS in direct seeded rice

ANOVA Table of first year 2021

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	0.05	3.34	NS
Treatment	14	295.42	21.10	51.66	2.06	S
Error	28	11.44	0.41			
Total	44	306.90				

ANOVA Table of second year 2022

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.37	0.18	0.56	3.34	NS
Treatment	14	236.52	16.89	51.49	2.06	S
Error	28	9.19	0.33			
Total	44	246.08				

ANOVA Table of Pooled

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Years	1	1.32	1.32	3.58	4.01	NS
Replication	4	0.41	0.10	0.28	2.54	NS
Treatment	14	513.57	36.68	99.60	1.87	S
Years x Treatment	14	18.38	1.31	3.56	1.87	S
Error	56	20.63	0.368			
Total	89	554.29				

ANOVA – I (b): Analysis of variance for effect of soil fertility management on plant height at 90 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	13.05	6.52	1.09	3.34	NS
Treatment	14	3924.05	280.29	46.67	2.06	S
Error	28	168.17	6.01			
Total	44	4105.27				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	8.85	4.43	0.66	3.34	NS
Treatment	14	4127.57	294.83	43.85	2.06	S
Error	28	188.24	6.72			
Total	44	4324.67				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	234.39	234.39	36.83	4.01	S
Replication	4	21.90	5.48	0.86	2.54	NS
Treatment	14	8006.64	571.90	89.86	1.87	S
Years x Treatment	14	44.98	3.21	0.50	1.87	NS
Error	56	356.41	6.365			
Total	89	8664.32				

ANOVA – I (c): Analysis of variance for effect of soil fertility management on plant height at harvest in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	43.54	21.77	2.71	3.34	NS
Treatment	14	6450.97	460.78	57.45	2.06	S
Error	28	224.60	8.02			
Total	44	6719.10				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.79	0.40	0.03	3.34	NS
Treatment	14	8784.26	627.45	39.72	2.06	S
Error	28	442.32	15.80			
Total	44	9227.37				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	828.59	828.59	69.57	4.01	S
Replication	4	44.33	11.08	0.93	2.54	NS
Treatment	14	14891.48	1063.68	89.31	1.87	S
Years x Treatment	14	343.75	24.55	2.06	1.87	S
Error	56	666.92	11.909			
Total	89	16775.06				

ANOVA – II (a): Analysis of variance for effect of soil fertility management on number of tillers m^{-2} at 45 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.14	0.07	0.80	3.34	NS
Treatment	14	11.43	0.82	9.24	2.06	S
Error	28	2.47	0.09			
Total	44	14.04				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.03	0.01	0.21	3.34	NS
Treatment	14	10.96	0.78	12.22	2.06	S
Error	28	1.79	0.06			
Total	44	12.78				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.79	1.79	23.53	4.01	S
Replication	4	0.17	0.04	0.55	2.54	NS
Treatment	14	22.19	1.59	20.81	1.87	S
Years x Treatment	14	0.19	0.01	0.18	1.87	NS
Error	56	4.27	0.076			
Total	89	28.61				

ANOVA – II (b): Analysis of variance for effect of soil fertility management on number of tillers m^{-2} at 90 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.28	0.14	2.12	3.34	NS
Treatment	14	29.45	2.10	31.49	2.06	S
Error	28	1.87	0.07			
Total	44	31.60				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	0.20	3.34	NS
Treatment	14	22.36	1.60	33.52	2.06	S
Error	28	1.33	0.05			
Total	44	23.72				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	2.84	2.84	49.71	4.01	S
Replication	4	0.30	0.08	1.32	2.54	NS
Treatment	14	51.33	3.67	64.07	1.87	S
Years x Treatment	14	0.48	0.03	0.60	1.87	NS
Error	56	3.20	0.057			
Total	89	58.16				

ANOVA – III (a): Analysis of variance for effect of soil fertility management on CGR at 0 - 45 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	1.05	3.34	NS
Treatment	14	9.25	0.66	168.69	2.06	S
Error	28	0.11	0.00			
Total	44	9.37				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	2.35	3.34	NS
Treatment	14	10.84	0.77	241.14	2.06	S
Error	28	0.09	0.00			
Total	44	10.94				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.42	0.42	116.79	4.01	S
Replication	4	0.02	0.01	1.63	2.54	NS
Treatment	14	20.00	1.43	400.80	1.87	S
Years x Treatment	14	0.09	0.01	1.83	1.87	NS
Error	56	0.20	0.004			
Total	89	20.73				

ANOVA – III (b): Analysis of variance for effect of soil fertility management on CGR at 45 - 90 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.92	3.34	NS
Treatment	14	8.89	0.64	1241.32	2.06	S
Error	28	0.01	0.00			
Total	44	8.91				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.57	3.34	NS
Treatment	14	8.58	0.61	1263.93	2.06	S
Error	28	0.01	0.00			
Total	44	8.60				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	16.49	4.01	S
Replication	4	0.00	0.00	0.75	2.54	NS
Treatment	14	17.42	1.24	2496.23	1.87	S
Years x Treatment	14	0.06	0.004	8.41	1.87	S
Error	56	0.03	0.0005			
Total	89	17.51				

ANOVA – IV (a): Analysis of variance for effect of soil fertility management on RGR at 0 - 45 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.44	3.34	NS
Treatment	14	0.00	0.00	2061.26	2.06	S
Error	28	0.00	0.00			
Total	44	0.00				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.83	3.34	NS
Treatment	14	0.00	0.00	4941.00	2.06	S
Error	28	0.00	0.00			
Total	44	0.00				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	539.71	4.01	S
Replication	4	0.00	0.00	0.86	2.54	NS
Treatment	14	0.00	0.00	5883.41	1.87	S
Years x Treatment	14	0.00	0.00	9.21	1.87	S
Error	56	0.00	0.000			
Total	89	0.00				

ANOVA – IV (b): Analysis of variance for effect of soil fertility management on RGR at 45 - 90 DAS in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.89	3.34	NS
Treatment	14	0.00	0.00	401.96	2.06	S
Error	28	0.00	0.00			
Total	44	0.00				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.00	3.34	NS
Treatment	14	0.00	0.00	14049.66	2.06	S
Error	28	0.00	0.00			
Total	44	0.00				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	251003.12	4.01	S
Replication	4	0.00	0.00	0.87	2.54	NS
Treatment	14	0.00	0.00	21.28	1.87	S
Years x Treatment	14	0.00	0.00	1320.96	1.87	S
Error	56	0.00	0.000			
Total	89	0.01				

ANOVA – V: Analysis of variance for effect of soil fertility management on number of panicles m^{-2} in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	7.78	3.89	0.62	3.34	NS
Treatment	14	386.98	27.64	4.39	2.06	S
Error	28	176.22	6.29			
Total	44	570.98				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.24	0.62	0.06	3.34	NS
Treatment	14	477.24	34.09	3.54	2.06	S
Error	28	269.42	9.62			
Total	44	747.91				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	127.21	127.21	15.99	4.01	S
Replication	4	9.02	2.26	0.28	2.54	NS
Treatment	14	846.27	60.45	7.60	1.87	S
Years x Treatment	14	17.96	1.28	0.16	1.87	NS
Error	56	445.64	7.958			
Total	89	1446.10				

ANOVA – VI: Analysis of variance for effect of soil fertility management on panicle length in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.23	1.11	1.04	3.34	NS
Treatment	14	13.09	0.94	0.87	2.06	NS
Error	28	30.07	1.07			
Total	44	45.39				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.17	1.08	0.98	3.34	NS
Treatment	14	13.65	0.98	0.88	2.06	NS
Error	28	30.94	1.11			
Total	44	46.76				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.00	4.01	**NS**
Replication	4	4.39	1.10	1.01	2.54	**NS**
Treatment	14	26.72	1.91	1.75	1.87	**NS**
Years x Treatment	14	0.02	0.00	0.00	1.87	**NS**
Error	56	61.01	1.090			
Total	89	92.16				

ANOVA – VII: Analysis of variance for effect of soil fertility management on number of grains panicle^{-1} in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	15.67	7.83	0.42	3.34	NS
Treatment	14	3810.86	272.20	14.55	2.06	S
Error	28	523.83	18.71			
Total	44	4350.36				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	28.19	14.09	1.08	3.34	NS
Treatment	14	3700.74	264.34	20.24	2.06	Significant
Error	28	365.73	13.06			
Total	44	4094.66				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	78.21	78.21	4.92	4.01	S
Replication	4	43.85	10.96	0.69	2.54	NS
Treatment	14	7491.27	535.09	33.69	1.87	S
Years x Treatment	14	20.33	1.45	0.09	1.87	NS
Error	56	889.57	15.885			
Total	89	8523.24				

ANOVA – VIII: Analysis of variance for effect of soil fertility management on number of filled grains panicle^{-1} in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	595.98	297.99	1.37	3.34	NS
Treatment	14	7020.79	501.49	2.30	2.06	S
Error	28	6093.60	217.63			
Total	44	13710.37				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	445.12	222.56	1.16	3.34	NS
Treatment	14	6491.09	463.65	2.41	2.06	S
Error	28	5385.49	192.34			
Total	44	12321.70				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	5.64	5.64	0.03	4.01	NS
Replication	4	1041.10	260.27	1.27	2.54	NS
Treatment	14	10795.73	771.12	3.76	1.87	S
Years x Treatment	14	2716.15	194.01	0.95	1.87	NS
Error	56	11479.09	204.984			
Total	89	26037.71				

ANOVA – IX: Analysis of variance for effect of soil fertility management on number of unfilled grains panicle^{-1} in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.46	0.73	1.87	3.34	NS
Treatment	14	64.60	4.61	11.81	2.06	S
Error	28	10.94	0.39			
Total	44	77.00				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.41	0.20	0.74	3.34	NS
Treatment	14	106.17	7.58	27.45	2.06	S
Error	28	7.74	0.28			
Total	44	114.31				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	8.18	8.18	24.53	4.01	S
Replication	4	1.87	0.47	1.40	2.54	NS
Treatment	14	165.09	11.79	35.36	1.87	S
Years x Treatment	14	5.68	0.41	1.22	1.87	NS
Error	56	18.67	0.333			
Total	89	199.50				

ANOVA – X: Analysis of variance for effect of soil fertility management on test weight (g) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.54	0.77	2.60	3.34	NS
Treatment	14	3.27	0.23	0.79	2.06	NS
Error	28	8.29	0.30			
Total	44	13.10				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.33	0.17	0.58	3.34	NS
Treatment	14	2.94	0.21	0.73	2.06	NS
Error	28	8.06	0.29			
Total	44	11.33				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.13	0.13	0.44	4.01	**NS**
Replication	4	1.87	0.47	1.60	2.54	**NS**
Treatment	14	5.95	0.42	1.46	1.87	**NS**
Years x Treatment	14	0.26	0.02	0.06	1.87	**NS**
Error	56	16.35	0.292			
Total	89	24.56				

ANOVA – XI: Analysis of variance for effect of soil fertility management on grain yield kg ha^{-1} in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	8609.64	4304.82	0.36	3.34	NS
Treatment	14	16157988.10	1154142.01	95.80	2.06	S
Error	28	337331.50	12047.55			
Total	44	16503929.25				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	11321.41	5660.70	0.65	3.34	NS
Treatment	14	18060271.40	1290019.39	148.88	2.06	S
Error	28	242618.95	8664.96			
Total	44	18314211.76				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	349004.67	349004.67	33.70	4.01	S
Replication	4	19931.05	4982.76	0.48	2.54	NS
Treatment	14	34157132.48	2439795.18	235.59	1.87	S
Years x Treatment	14	61127.03	4366.22	0.42	1.87	NS
Error	56	579950.45	10356.258			
Total	89	35167145.69				

ANOVA – XII: Analysis of variance for effect of soil fertility management on straw yield kg ha^{-1} in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	3046.80	1523.40	0.35	3.34	NS
Treatment	14	10871254.53	776518.18	177.95	2.06	S
Error	28	122183.87	4363.71			
Total	44	10996485.20				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	15870.40	7935.20	0.90	3.34	NS
Treatment	14	11243165.87	803083.28	91.34	2.06	S
Error	28	246180.93	8792.18			
Total	44	11505217.20				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1631352.10	1631352.10	248.00	4.01	S
Replication	4	18917.20	4729.30	0.72	2.54	NS
Treatment	14	21705390.33	1550385.02	235.69	1.87	S
Years x Treatment	14	409030.07	29216.43	4.44	1.87	S
Error	56	368364.80	6577.943			
Total	89	24133054.50				

ANOVA – XIII: Analysis of variance for effect of soil fertility management on harvest index (%) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.04	0.02	0.05	3.34	NS
Treatment	14	295.42	21.10	51.66	2.06	S
Error	28	11.44	0.41			
Total	44	306.90				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.37	0.18	0.56	3.34	NS
Treatment	14	236.52	16.89	51.49	2.06	S
Error	28	9.19	0.33			
Total	44	246.08				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.32	1.32	3.58	4.01	NS
Replication	4	0.41	0.10	0.28	2.54	NS
Treatment	14	513.57	36.68	99.60	1.87	S
Years x Treatment	14	18.38	1.31	3.56	1.87	S
Error	56	20.63	0.368			
Total	89	554.29				

ANOVA – XIV: Analysis of variance for effect of soil fertility management on nitrogen content (%) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.46	3.34	NS
Treatment	14	0.24	0.02	16.09	2.06	S
Error	28	0.03	0.00			
Total	44	0.27				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.89	3.34	NS
Treatment	14	0.20	0.01	15.74	2.06	S
Error	28	0.03	0.00			
Total	44	0.23				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	3.57	4.01	NS
Replication	4	0.00	0.00	1.20	2.54	NS
Treatment	14	0.43	0.03	31.65	1.87	S
Years x Treatment	14	0.00	0.00	0.20	1.87	NS
Error	56	0.05	0.001			
Total	89	0.50				

ANOVA – XV: Analysis of variance for effect of soil fertility management on nitrogen content (%) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.09	3.34	NS
Treatment	14	0.03	0.00	24.49	2.06	S
Error	28	0.00	0.00			
Total	44	0.03				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	2.60	3.34	NS
Treatment	14	0.03	0.00	27.06	2.06	S
Error	28	0.00	0.00			
Total	44	0.03				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	26.69	4.01	S
Replication	4	0.00	0.00	1.80	2.54	NS
Treatment	14	0.06	0.00	50.89	1.87	S
Years x Treatment	14	0.00	0.00	0.49	1.87	NS
Error	56	0.00	0.00			
Total	89	0.07				

ANOVA – XVI: Analysis of variance for effect of soil fertility management on phosphorus content (%) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	3.17	3.34	NS
Treatment	14	0.04	0.00	32.07	2.06	S
Error	28	0.00	0.00			
Total	44	0.05				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.69	3.34	NS
Treatment	14	0.04	0.00	13.87	2.06	S
Error	28	0.01	0.00			
Total	44	0.05				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	56.60	4.01	S
Replication	4	0.00	0.00	2.17	2.54	NS
Treatment	14	0.08	0.01	39.12	1.87	S
Years x Treatment	14	0.00	0.00	0.28	1.87	NS
Error	56	0.01	0.00			
Total	89	0.10				

ANOVA – XVII: Analysis of variance for effect of soil fertility management on phosphorus content (%) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.28	3.34	NS
Treatment	14	0.00	0.00	54.03	2.06	S
Error	28	0.00	0.00			
Total	44	0.00				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.85	3.34	NS
Treatment	14	0.00	0.00	128.61	2.06	S
Error	28	0.00	0.00			
Total	44	0.00				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	36.82	4.01	S
Replication	4	0.00	0.00	0.69	2.54	NS
Treatment	14	0.00	0.00	144.87	1.87	S
Years x Treatment	14	0.00	0.00	2.30	1.87	S
Error	56	0.00	0.00			
Total	89	0.00				

ANOVA – XVIII: Analysis of variance for effect of soil fertility management on potassium content (%) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.30	3.34	NS
Treatment	14	0.06	0.00	12.48	2.06	S
Error	28	0.01	0.00			
Total	44	0.07				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.29	3.34	NS
Treatment	14	0.06	0.00	14.88	2.06	S
Error	28	0.01	0.00			
Total	44	0.07				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	8.80	4.01	S
Replication	4	0.00	0.00	0.29	2.54	NS
Treatment	14	0.12	0.01	26.92	1.87	S
Years x Treatment	14	0.00	0.00	0.16	1.87	NS
Error	56	0.02	0.00			
Total	89	0.14				

ANOVA – XIX: Analysis of variance for effect of soil fertility management on potassium content (%) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.62	3.34	NS
Treatment	14	0.30	0.02	3368.41	2.06	S
Error	28	0.00	0.00			
Total	44	0.30				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.53	3.34	NS
Treatment	14	0.31	0.02	6913.79	2.06	S
Error	28	0.00	0.00			
Total	44	0.31				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	1802.54	4.01	S
Replication	4	0.00	0.00	1.26	2.54	NS
Treatment	14	0.61	0.04	9061.87	1.87	S
Years x Treatment	14	0.00	0.00	16.24	1.87	S
Error	56	0.00	0.00			
Total	89	0.62				

ANOVA – XX: Analysis of variance for effect of soil fertility management on sulphur content (%) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.09	3.34	NS
Treatment	14	0.18	0.01	71.86	2.06	S
Error	28	0.01	0.00			
Total	44	0.19				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.18	3.34	NS
Treatment	14	0.21	0.01	98.84	2.06	S
Error	28	0.00	0.00			
Total	44	0.21				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	20.95	4.01	S
Replication	4	0.00	0.00	0.13	2.54	NS
Treatment	14	0.39	0.03	167.31	1.87	S
Years x Treatment	14	0.00	0.00	0.81	1.87	NS
Error	56	0.01	0.00			
Total	89	0.40				

ANOVA – XXI: Analysis of variance for effect of soil fertility management on sulphur content (%) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.07	3.34	NS
Treatment	14	0.02	0.00	4.08	2.06	S
Error	28	0.01	0.00			
Total	44	0.03				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.19	3.34	NS
Treatment	14	0.02	0.00	2.90	2.06	S
Error	28	0.01	0.00			
Total	44	0.03				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	2.96	4.01	NS
Replication	4	0.00	0.00	1.14	2.54	NS
Treatment	14	0.03	0.00	6.51	1.87	S
Years x Treatment	14	0.00	0.00	0.30	1.87	NS
Error	56	0.02	0.00			
Total	89	0.05				

ANOVA – XXII: Analysis of variance for effect of soil fertility management on calcium content (%) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.65	3.34	NS
Treatment	14	0.00	0.00	1.49	2.06	NS
Error	28	0.01	0.00			
Total	44	0.01				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	2.76	3.34	NS
Treatment	14	0.00	0.00	0.69	2.06	NS
Error	28	0.01	0.00			
Total	44	0.01				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.49	4.01	NS
Replication	4	0.00	0.00	2.20	2.54	NS
Treatment	14	0.01	0.00	1.87	1.87	NS
Years x Treatment	14	0.00	0.00	0.32	1.87	NS
Error	56	0.01	0.00			
Total	89	0.02				

ANOVA – XXIII: Analysis of variance for effect of soil fertility management on calcium content (%) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	1.56	3.34	NS
Treatment	14	0.02	0.00	0.83	2.06	NS
Error	28	0.05	0.00			
Total	44	0.07				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.42	3.34	NS
Treatment	14	0.01	0.00	0.83	2.06	NS
Error	28	0.03	0.00			
Total	44	0.05				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	5.78	4.01	S
Replication	4	0.01	0.00	1.11	2.54	NS
Treatment	14	0.03	0.00	1.57	1.87	NS
Years x Treatment	14	0.00	0.00	0.09	1.87	NS
Error	56	0.08	0.00			
Total	89	0.13				

ANOVA – XXIV: Analysis of variance for effect of soil fertility management on zinc content (mg kg^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	7.28	3.64	1.75	3.34	NS
Treatment	14	28.60	2.04	0.98	2.06	NS
Error	28	58.20	2.08			
Total	44	94.08				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	15.01	7.50	3.21	3.34	NS
Treatment	14	28.63	2.04	0.87	2.06	NS
Error	28	65.52	2.34			
Total	44	109.15				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.10	0.10	0.04	4.01	NS
Replication	4	22.28	5.57	2.52	2.54	NS
Treatment	14	57.20	4.09	1.85	1.87	NS
Years x Treatment	14	0.03	0.00	0.00	1.87	NS
Error	56	123.72	2.21			
Total	89	203.34				

ANOVA – XXV: Analysis of variance for effect of soil fertility management on zinc content (mg kg^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	20.56	10.28	1.22	3.34	NS
Treatment	14	91.73	6.55	0.78	2.06	NS
Error	28	236.22	8.44			
Total	44	348.51				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	19.30	9.65	1.39	3.34	NS
Treatment	14	92.04	6.57	0.95	2.06	NS
Error	28	193.73	6.92			
Total	44	305.07				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.04	0.04	0.00	4.01	NS
Replication	4	39.86	9.97	1.30	2.54	NS
Treatment	14	183.76	13.13	1.71	1.87	NS
Years x Treatment	14	0.02	0.00	0.00	1.87	NS
Error	56	429.95	7.68			
Total	89	653.62				

ANOVA – XXVI: Analysis of variance for effect of soil fertility management on iron content (mg kg^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	5.88	2.94	1.01	3.34	NS
Treatment	14	41.02	2.93	1.01	2.06	NS
Error	28	81.17	2.90			
Total	44	128.07				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	6.52	3.26	0.93	3.34	NS
Treatment	14	41.92	2.99	0.85	2.06	NS
Error	28	98.73	3.53			
Total	44	147.18				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.09	0.09	0.03	4.01	NS
Replication	4	12.40	3.10	0.97	2.54	NS
Treatment	14	82.69	5.91	1.84	1.87	NS
Years x Treatment	14	0.25	0.02	0.01	1.87	NS
Error	56	179.90	3.21			
Total	89	275.33				

ANOVA – XXVII: Analysis of variance for effect of soil fertility management on iron content (mg kg^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	12.32	6.16	1.51	3.34	NS
Treatment	14	56.15	4.01	0.98	2.06	NS
Error	28	114.48	4.09			
Total	44	182.96				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	9.94	4.97	1.10	3.34	**NS**
Treatment	14	54.75	3.91	0.87	2.06	**NS**
Error	28	126.06	4.50			
Total	44	190.75				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	0.00	4.01	NS
Replication	4	22.26	5.56	1.30	2.54	NS
Treatment	14	110.71	7.91	1.84	1.87	NS
Years x Treatment	14	0.20	0.01	0.00	1.87	NS
Error	56	240.55	4.30			
Total	89	373.72				

ANOVA – XXVIII: Analysis of variance for effect of soil fertility management on manganese content (mg kg^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	101.33	50.66	3.17	3.34	NS
Treatment	14	236.47	16.89	1.06	2.06	NS
Error	28	447.25	15.97			
Total	44	785.05				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	19.71	9.85	0.49	3.34	NS
Treatment	14	233.65	16.69	0.83	2.06	NS
Error	28	566.25	20.22			
Total	44	819.60				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.14	0.14	0.01	4.01	NS
Replication	4	121.03	30.26	1.67	2.54	NS
Treatment	14	470.10	33.58	1.86	1.87	NS
Years x Treatment	14	0.02	0.002	0.0001	1.87	NS
Error	56	1013.50	18.10			
Total	89	1604.80				

ANOVA – XXIX: Analysis of variance for effect of soil fertility management on manganese content (mg kg^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	13.19	6.59	0.99	3.34	NS
Treatment	14	67.15	4.80	0.72	2.06	NS
Error	28	187.02	6.68			
Total	44	267.36				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	13.39	6.69	1.01	3.34	NS
Treatment	14	51.65	3.69	0.55	2.06	NS
Error	28	186.42	6.66			
Total	44	251.46				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.59	0.59	0.09	4.01	NS
Replication	4	26.57	6.64	1.00	2.54	NS
Treatment	14	116.57	8.33	1.25	1.87	NS
Years x Treatment	14	2.23	0.16	0.02	1.87	NS
Error	56	373.44	6.67			
Total	89	519.40				

ANOVA – XXX: Analysis of variance for effect of soil fertility management on copper content (mg kg^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.22	0.61	0.23	3.34	NS
Treatment	14	34.33	2.45	0.92	2.06	NS
Error	28	74.28	2.65			
Total	44	109.83				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.12	0.06	0.02	3.34	NS
Treatment	14	34.38	2.46	0.93	2.06	NS
Error	28	74.17	2.65			
Total	44	108.68				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.09	0.09	0.03	4.01	NS
Replication	4	1.34	0.34	0.13	2.54	NS
Treatment	14	68.64	4.90	1.85	1.87	NS
Years x Treatment	14	0.08	0.01	0.002	1.87	NS
Error	56	148.45	2.65			
Total	89	218.59				

ANOVA – XXXI: Analysis of variance for effect of soil fertility management on copper content (mg kg^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	12.02	6.01	1.38	3.34	NS
Treatment	14	54.36	3.88	0.89	2.06	NS
Error	28	122.12	4.36			
Total	44	188.51				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	16.79	8.40	2.43	3.34	NS
Treatment	14	47.38	3.38	0.98	2.06	NS
Error	28	96.91	3.46			
Total	44	161.08				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	0.00	4.01	NS
Replication	4	28.81	7.20	1.84	2.54	NS
Treatment	14	101.15	7.22	1.85	1.87	NS
Years x Treatment	14	0.60	0.04	0.01	1.87	NS
Error	56	219.03	3.91			
Total	89	349.60				

ANOVA – XXXII: Analysis of variance for effect of soil fertility management on nitrogen uptake (kg ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	6.84	3.42	2.07	3.34	NS
Treatment	14	3421.92	244.42	147.79	2.06	S
Error	28	46.31	1.65			
Total	44	3475.06				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.32	0.66	0.32	3.34	NS
Treatment	14	3696.18	264.01	126.43	2.06	S
Error	28	58.47	2.09			
Total	44	3755.97				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	77.03	77.03	41.17	4.01	S
Replication	4	8.16	2.04	1.09	2.54	NS
Treatment	14	7108.66	507.76	271.39	1.87	S
Years x Treatment	14	9.43	0.67	0.36	1.87	NS
Error	56	104.78	1.87			
Total	89	7308.07				

ANOVA – XXXIII: Analysis of variance for effect of soil fertility management on nitrogen uptake (kg ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.93	0.47	1.01	3.34	NS
Treatment	14	600.20	42.87	92.69	2.06	S
Error	28	12.95	0.46			
Total	44	614.09				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.31	0.15	0.36	3.34	NS
Treatment	14	614.35	43.88	104.51	2.06	S
Error	28	11.76	0.42			
Total	44	626.41				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	72.99	72.99	165.42	4.01	S
Replication	4	1.24	0.31	0.70	2.54	NS
Treatment	14	1203.27	85.95	194.80	1.87	S
Years x Treatment	14	11.28	0.81	1.83	1.87	NS
Error	56	24.71	0.44			
Total	89	1313.48				

ANOVA – XXXIV: Analysis of variance for effect of soil fertility management on phosphorus uptake (kg ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.81	0.41	2.31	3.34	NS
Treatment	14	264.12	18.87	106.90	2.06	S
Error	28	4.94	0.18			
Total	44	269.88				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.51	0.75	2.25	3.34	NS
Treatment	14	316.15	22.58	67.32	2.06	S
Error	28	9.39	0.34			
Total	44	327.05				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	23.41	23.41	91.44	4.01	S
Replication	4	2.32	0.58	2.27	2.54	NS
Treatment	14	577.82	41.27	161.25	1.87	S
Years x Treatment	14	2.45	0.18	0.68	1.87	NS
Error	56	14.33	0.26			
Total	89	620.34				

ANOVA – XXXV: Analysis of variance for effect of soil fertility management on phosphorus uptake (kg ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.01	3.34	NS
Treatment	14	18.63	1.33	258.89	2.06	S
Error	28	0.14	0.01			
Total	44	18.77				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	1.61	3.34	NS
Treatment	14	18.26	1.30	173.92	2.06	S
Error	28	0.21	0.01			
Total	44	18.49				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.75	1.75	276.61	4.01	S
Replication	4	0.02	0.01	0.96	2.54	NS
Treatment	14	36.69	2.62	414.72	1.87	S
Years x Treatment	14	0.20	0.01	2.22	1.87	S
Error	56	0.35	0.01			
Total	89	39.01				

ANOVA – XXXVI: Analysis of variance for effect of soil fertility management on potassium uptake (kg ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.55	0.27	0.42	3.34	NS
Treatment	14	562.27	40.16	62.12	2.06	S
Error	28	18.10	0.65			
Total	44	580.92				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.49	0.25	0.53	3.34	NS
Treatment	14	622.95	44.50	95.76	2.06	S
Error	28	13.01	0.46			
Total	44	636.45				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	18.08	18.08	32.55	4.01	S
Replication	4	1.04	0.26	0.47	2.54	NS
Treatment	14	1182.82	84.49	152.07	1.87	S
Years x Treatment	14	2.40	0.17	0.31	1.87	NS
Error	56	31.11	0.56			
Total	89	1235.46				

ANOVA – XXXVII: Analysis of variance for effect of soil fertility management on potassium uptake (kg ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.23	0.12	0.19	3.34	NS
Treatment	14	4507.72	321.98	527.31	2.06	S
Error	28	17.10	0.61			
Total	44	4525.05				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.24	1.12	0.83	3.34	NS
Treatment	14	4676.52	334.04	248.03	2.06	S
Error	28	37.71	1.35			
Total	44	4716.46				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	412.98	412.98	421.98	4.01	S
Replication	4	2.47	0.62	0.63	2.54	NS
Treatment	14	9121.59	651.54	665.74	1.87	S
Years x Treatment	14	62.65	4.48	4.57	1.87	S
Error	56	54.81	0.98			
Total	89	9654.49				

ANOVA – XXXVIII: Analysis of variance for effect of soil fertility management on sulphur uptake (kg ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.01	0.01	3.34	NS
Treatment	14	793.44	56.67	113.58	2.06	S
Error	28	13.97	0.50			
Total	44	807.43				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.15	0.08	0.19	3.34	NS
Treatment	14	961.69	68.69	173.32	2.06	Significant
Error	28	11.10	0.40			
Total	44	972.93				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	22.02	22.02	49.18	4.01	S
Replication	4	0.16	0.04	0.09	2.54	NS
Treatment	14	1749.03	124.93	279.07	1.87	S
Years x Treatment	14	6.10	0.44	0.97	1.87	NS
Error	56	25.07	0.45			
Total	89	1802.38				

ANOVA – XXXIX: Analysis of variance for effect of soil fertility management on sulphur uptake (kg ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.78	0.89	1.09	3.34	NS
Treatment	14	151.86	10.85	13.23	2.06	S
Error	28	22.95	0.82			
Total	44	176.59				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.13	1.06	0.90	3.34	NS
Treatment	14	160.06	11.43	9.67	2.06	S
Error	28	33.09	1.18			
Total	44	195.28				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	18.12	18.12	18.10	4.01	S
Replication	4	3.91	0.98	0.98	2.54	NS
Treatment	14	307.10	21.94	21.92	1.87	S
Years x Treatment	14	4.81	0.34	0.34	1.87	NS
Error	56	56.04	1.00			
Total	89	389.98				

ANOVA – XL: Analysis of variance for effect of soil fertility management on calcium uptake (kg ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.09	0.55	3.04	3.34	NS
Treatment	14	27.95	2.00	11.12	2.06	S
Error	28	5.03	0.18			
Total	44	34.07				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.85	0.93	3.30	3.34	NS
Treatment	14	21.50	1.54	5.47	2.06	S
Error	28	7.86	0.28			
Total	44	31.21				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.56	0.56	2.44	4.01	NS
Replication	4	2.94	0.74	3.20	2.54	S
Treatment	14	48.32	3.45	14.99	1.87	St
Years x Treatment	14	1.13	0.08	0.35	1.87	NS
Error	56	12.89	0.23			
Total	89	65.85				

ANOVA – XLI: Analysis of variance for effect of soil fertility management on calcium uptake (kg ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	15.37	7.68	1.80	3.34	NS
Treatment	14	1479.67	105.69	24.81	2.06	S
Error	28	119.28	4.26			
Total	44	1614.31				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	4.14	2.07	0.71	3.34	NS
Treatment	14	1585.68	113.26	39.04	2.06	S
Error	28	81.23	2.90			
Total	44	1671.05				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	328.25	328.25	91.68	4.01	S
Replication	4	19.51	4.88	1.36	2.54	NS
Treatment	14	3025.04	216.07	60.35	1.87	S
Years x Treatment	14	40.30	2.88	0.80	1.87	NS
Error	56	200.50	3.58			
Total	89	3613.61				

ANOVA – XLII: Analysis of variance for effect of soil fertility management on zinc uptake (g ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	159.97	79.99	2.71	3.34	NS
Treatment	14	17709.68	1264.98	42.84	2.06	S
Error	28	826.83	29.53			
Total	44	18696.48				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	216.51	108.25	2.37	3.34	NS
Treatment	14	19770.07	1412.15	30.90	2.06	S
Error	28	1279.59	45.70			
Total	44	21266.17				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	342.21	342.21	9.10	4.01	S
Replication	4	376.48	94.12	2.50	2.54	NS
Treatment	14	37426.09	2673.29	71.07	1.87	S
Years x Treatment	14	53.66	3.83	0.10	1.87	NS
Error	56	2106.42	37.61			
Total	89	40304.86				

ANOVA – XLIII: Analysis of variance for effect of soil fertility management on zinc uptake (g ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	688.91	344.45	1.57	3.34	NS
Treatment	14	34695.18	2478.23	11.28	2.06	S
Error	28	6150.65	219.67			
Total	44	41534.74				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	480.20	240.10	1.35	3.34	NS
Treatment	14	35166.64	2511.90	14.12	2.06	S
Error	28	4981.56	177.91			
Total	44	40628.40				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	3070.50	3070.50	15.45	4.01	S
Replication	4	1169.10	292.28	1.47	2.54	NS
Treatment	14	69182.28	4941.59	24.86	1.87	S
Years x Treatment	14	679.55	48.54	0.24	1.87	NS
Error	56	11132.21	198.79			
Total	89	85233.63				

ANOVA – XLIV: Analysis of variance for effect of soil fertility management on iron uptake (g ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	98.74	49.37	0.82	3.34	NS
Treatment	14	57353.44	4096.67	68.08	2.06	S
Error	28	1684.80	60.17			
Total	44	59136.98				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	83.41	41.70	0.63	3.34	NS
Treatment	14	63531.56	4537.97	68.78	2.06	S
Error	28	1847.46	65.98			
Total	44	65462.43				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1216.70	1216.70	19.29	4.01	S
Replication	4	182.15	45.54	0.72	2.54	NS
Treatment	14	120689.51	8620.68	136.67	1.87	S
Years x Treatment	14	195.50	13.96	0.22	1.87	NS
Error	56	3532.25	63.08			
Total	89	125816.11				

ANOVA – XLV: Analysis of variance for effect of soil fertility management on iron uptake (g ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	468.90	234.45	1.66	3.34	NS
Treatment	14	122991.61	8785.11	62.35	2.06	S
Error	28	3944.99	140.89			
Total	44	127405.50				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	56.97	28.49	0.16	3.34	NS
Treatment	14	126610.05	9043.58	50.56	2.06	S
Error	28	5008.29	178.87			
Total	44	131675.31				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	15075.11	15075.11	94.29	4.01	S
Replication	4	525.87	131.47	0.82	2.54	NS
Treatment	14	245913.77	17565.27	109.87	1.87	S
Years x Treatment	14	3687.89	263.42	1.65	1.87	NS
Error	56	8953.28	159.88			
Total	89	274155.92				

ANOVA – XLVI: Analysis of variance for effect of soil fertility management on manganese uptake (g ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	915.08	457.54	2.38	3.34	NS
Treatment	14	55256.66	3946.90	20.51	2.06	S
Error	28	5387.94	192.43			
Total	44	61559.67				

ANOVA Table of second year 2022

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	293.76	146.88	0.59	3.34	NS
Treatment	14	61029.86	4359.28	17.38	2.06	S
Error	28	7022.74	250.81			
Total	44	68346.36				

ANOVA Table of Pooled

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Years	1	850.09	850.09	3.84	4.01	NS
Replication	4	1208.83	302.21	1.36	2.54	NS
Treatment	14	116145.55	8296.11	37.43	1.87	S
Years x Treatment	14	140.97	10.07	0.05	1.87	NS
Error	56	12410.68	221.62			
Total	89	130756.12				

ANOVA – XLVII: Analysis of variance for effect of soil fertility management on manganese uptake (g ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	352.95	176.48	1.11	3.34	NS
Treatment	14	64920.95	4637.21	29.06	2.06	S
Error	28	4468.60	159.59			
Total	44	69742.50				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	309.43	154.72	0.87	3.34	NS
Treatment	14	64245.92	4588.99	25.83	2.06	S
Error	28	4974.60	177.66			
Total	44	69529.95				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	7543.80	7543.80	44.74	4.01	S
Replication	4	662.39	165.60	0.98	2.54	NS
Treatment	14	127486.87	9106.21	54.00	1.87	S
Years x Treatment	14	1679.99	120.00	0.71	1.87	NS
Error	56	9443.20	168.63			
Total	89	146816.26				

ANOVA – XLVIII: Analysis of variance for effect of soil fertility management on copper uptake (g ha^{-1}) in grain in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	11.25	5.63	0.15	3.34	NS
Treatment	14	2055.28	146.81	4.04	2.06	S
Error	28	1016.37	36.30			
Total	44	3082.90				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	15.17	7.58	0.22	3.34	NS
Treatment	14	2285.29	163.24	4.63	2.06	S
Error	28	987.49	35.27			
Total	44	3287.95				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	24.56	24.56	0.69	4.01	NS
Replication	4	26.42	6.60	0.18	2.54	NS
Treatment	14	4334.61	309.62	8.65	1.87	S
Years x Treatment	14	5.96	0.43	0.01	1.87	NS
Error	56	2003.86	35.78			
Total	89	6395.41				

ANOVA – XLIX: Analysis of variance for effect of soil fertility management on copper uptake (g ha^{-1}) in straw in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	402.42	201.21	1.71	3.34	NS
Treatment	14	4682.00	334.43	2.84	2.06	S
Error	28	3294.86	117.67			
Total	44	8379.28				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	563.50	281.75	3.08	3.34	NS
Treatment	14	4501.34	321.52	3.51	2.06	S
Error	28	2563.50	91.55			
Total	44	7628.33				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	132.66	132.66	1.27	4.01	**NS**
Replication	4	965.92	241.48	2.31	2.54	**NS**
Treatment	14	9129.89	652.13	6.23	1.87	**Significant**
Years x Treatment	14	53.45	3.82	0.04	1.87	**NS**
Error	56	5858.36	104.61			
Total	89	16140.28				

ANOVA – L: Analysis of variance for effect of soil fertility management on total nitrogen uptake (kg ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	9.58	4.79	2.41	3.34	NS
Treatment	14	6785.82	484.70	244.23	2.06	S
Error	28	55.57	1.98			
Total	44	6850.97				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.08	1.04	0.36	3.34	NS
Treatment	14	7230.00	516.43	180.51	2.06	S
Error	28	80.10	2.86			
Total	44	7312.18				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	300.11	300.11	123.87	4.01	S
Replication	4	11.66	2.92	1.20	2.54	NS
Treatment	14	13995.13	999.65	412.61	1.87	S
Years x Treatment	14	20.68	1.48	0.61	1.87	NS
Error	56	135.67	2.423			
Total	89	14463.26				

ANOVA – LI: Analysis of variance for effect of soil fertility management on total phosphorus uptake (kg ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.80	0.40	2.14	3.34	NS
Treatment	14	420.79	30.06	160.76	2.06	S
Error	28	5.23	0.19			
Total	44	426.82				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.91	0.96	2.70	3.34	NS
Treatment	14	481.42	34.39	96.91	2.06	S
Error	28	9.94	0.35			
Total	44	493.26				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	37.95	37.95	140.07	4.01	S
Replication	4	2.71	0.68	2.50	2.54	NS
Treatment	14	899.74	64.27	237.23	1.87	S
Years x Treatment	14	2.47	0.18	0.65	1.87	NS
Error	56	15.17	0.271			
Total	89	958.03				

ANOVA – LII: Analysis of variance for effect of soil fertility management on total potassium uptake (kg ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.91	0.45	0.29	3.34	NS
Treatment	14	8225.77	587.55	370.82	2.06	S
Error	28	44.36	1.58			
Total	44	8271.04				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	4.66	2.33	1.04	3.34	NS
Treatment	14	8650.85	617.92	274.69	2.06	S
Error	28	62.99	2.25			
Total	44	8718.51				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	603.90	603.90	315.02	4.01	S
Replication	4	5.57	1.39	0.73	2.54	NS
Treatment	14	16811.83	1200.85	626.42	1.87	S
Years x Treatment	14	64.79	4.63	2.41	1.87	S
Error	56	107.35	1.917			
Total	89	17593.45				

ANOVA – LIII: Analysis of variance for effect of soil fertility management on total sulphur uptake (kg ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.77	0.89	0.70	3.34	NS
Treatment	14	1572.05	112.29	88.38	2.06	S
Error	28	35.57	1.27			
Total	44	1609.39				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.16	0.58	0.43	3.34	NS
Treatment	14	1811.06	129.36	95.43	2.06	S
Error	28	37.96	1.36			
Total	44	1850.17				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	80.07	80.07	60.98	4.01	S
Replication	4	2.93	0.73	0.56	2.54	NS
Treatment	14	3373.55	240.97	183.52	1.87	S
Years x Treatment	14	9.55	0.68	0.52	1.87	NS
Error	56	73.53	1.313			
Total	89	3539.64				

ANOVA – LIV: Analysis of variance for effect of soil fertility management on total calcium uptake (kg ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	24.65	12.32	3.33	3.34	NS
Treatment	14	1899.40	135.67	36.72	2.06	S
Error	28	103.47	3.70			
Total	44	2027.51				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.46	1.23	0.36	3.34	NS
Treatment	14	1957.08	139.79	41.24	2.06	S
Error	28	94.91	3.39			
Total	44	2054.44				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	355.95	355.95	100.48	4.01	S
Replication	4	27.10	6.78	1.91	2.54	NS
Treatment	14	3815.66	272.55	76.94	1.87	S
Years x Treatment	14	40.82	2.92	0.82	1.87	NS
Error	56	198.38	3.542			
Total	89	4437.90				

ANOVA – LV: Analysis of variance for effect of soil fertility management on total zinc uptake (g ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	766.30	383.15	1.46	3.34	NS
Treatment	14	100484.67	7177.48	27.29	2.06	S
Error	28	7363.39	262.98			
Total	44	108614.36				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	886.81	443.41	1.82	3.34	NS
Treatment	14	105692.35	7549.45	31.07	2.06	S
Error	28	6804.48	243.02			
Total	44	113383.65				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	5462.85	5462.85	21.59	4.01	S
Replication	4	1653.12	413.28	1.63	2.54	NS
Treatment	14	205459.55	14675.68	58.01	1.87	S
Years x Treatment	14	717.47	51.25	0.20	1.87	NS
Error	56	14167.87	252.998			
Total	89	227460.86				

ANOVA – LVI: Analysis of variance for effect of soil fertility management on total iron uptake (g ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	818.97	409.48	1.28	3.34	NS
Treatment	14	343261.88	24518.71	76.67	2.06	S
Error	28	8954.37	319.80			
Total	44	353035.21				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	265.94	132.97	0.35	3.34	NS
Treatment	14	360550.67	25753.62	68.14	2.06	S
Error	28	10581.99	377.93			
Total	44	371398.59				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	24857.30	24857.30	71.25	4.01	S
Replication	4	1084.90	271.23	0.78	2.54	NS
Treatment	14	700043.05	50003.07	143.33	1.87	S
Years x Treatment	14	3769.50	269.25	0.77	1.87	NS
Error	56	19536.35	348.863			
Total	89	749291.10				

ANOVA – LVII: Analysis of variance for effect of soil fertility management on total manganese uptake (g ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1788.05	894.02	1.89	3.34	NS
Treatment	14	236931.18	16923.66	35.73	2.06	S
Error	28	13262.50	473.66			
Total	44	251981.73				

ANOVA Table of second year						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	437.72	218.86	0.37	3.34	NS
Treatment	14	245001.92	17500.14	29.90	2.06	S
Error	28	16385.78	585.21			
Total	44	261825.42				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	13458.65	13458.65	25.42	4.01	S
Replication	4	2225.77	556.44	1.05	2.54	NS
Treatment	14	480225.83	34301.84	64.79	1.87	S
Years x Treatment	14	1707.28	121.95	0.23	1.87	NS
Error	56	29648.28	529.434			
Total	89	527265.80				

ANOVA – LVIII: Analysis of variance for effect of soil fertility management on total copper uptake (g ha^{-1}) in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	547.79	273.90	1.78	3.34	NS
Treatment	14	12838.60	917.04	5.95	2.06	S
Error	28	4317.41	154.19			
Total	44	17703.80				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	657.04	328.52	2.40	3.34	NS
Treatment	14	13074.66	933.90	6.82	2.06	S
Error	28	3836.68	137.02			
Total	44	17568.38				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	271.39	271.39	1.86	4.01	NS
Replication	4	1204.83	301.21	2.07	2.54	NS
Treatment	14	25869.40	1847.81	12.69	1.87	S
Years x Treatment	14	43.87	3.13	0.02	1.87	NS
Error	56	8154.09	145.609			
Total	89	35543.57				

ANOVA – LIX: Analysis of variance for effect of soil fertility management on pH in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.03	0.01	0.36	3.34	NS
Treatment	14	7.41	0.53	13.67	2.06	S
Error	28	1.08	0.04			
Total	44	8.52				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.19	0.09	3.21	3.34	NS
Treatment	14	7.03	0.50	17.22	2.06	S
Error	28	0.82	0.03			
Total	44	8.03				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.02	0.02	0.73	4.01	NS
Replication	4	0.21	0.05	1.58	2.54	NS
Treatment	14	14.39	1.03	30.31	1.87	S
Years x Treatment	14	0.04	0.00	0.08	1.87	NS
Error	56	1.90	0.034			
Total	89	16.57				

ANOVA – LX: Analysis of variance for effect of soil fertility management on EC in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.0001	0.00004	0.60	3.34	NS
Treatment	14	0.001	0.00009	1.24	2.06	NS
Error	28	0.002	0.00007			
Total	44	0.003				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00001	0.00001	0.17	3.34	NS
Treatment	14	0.00059	0.00004	1.05	2.06	NS
Error	28	0.00112	0.00004			
Total	44	0.00172				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.000004	0.000004	0.08	4.01	NS
Replication	4	0.000098	0.000024	0.44	2.54	NS
Treatment	14	0.001389	0.000099	1.79	1.87	NS
Years x Treatment	14	0.000429	0.000031	0.55	1.87	NS
Error	56	0.003102	0.000055			
Total	89	0.01				

ANOVA – LXI: Analysis of variance for effect of soil fertility management on bulk density in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.001	0.0005	1.41	3.34	NS
Treatment	14	0.003	0.0002	0.65	2.06	NS
Error	28	0.009	0.0003			
Total	44	0.01				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.0001	0.0001	0.27	3.34	NS
Treatment	14	0.003	0.0003	1.24	2.06	NS
Error	28	0.006	0.0002			
Total	44	0.01				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.000001	0.000001	0.004	4.01	NS
Replication	4	0.001	0.0002	0.96	2.54	NS
Treatment	14	0.006	0.0004	1.71	1.87	NS
Years x Treatment	14	0.0002	0.00001	0.05	1.87	NS
Error	56	0.01	0.0002			
Total	89	0.02				

ANOVA – LXII: Analysis of variance for effect of soil fertility management on organic carbon in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	0.09	3.34	NS
Treatment	14	71.60	5.11	41.75	2.06	S
Error	28	3.43	0.12			
Total	44	75.05				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.06	0.03	0.36	3.34	NS
Treatment	14	67.12	4.79	59.08	2.06	S
Error	28	2.27	0.08			
Total	44	69.45				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.83	0.83	8.13	4.01	S
Replication	4	0.08	0.02	0.20	2.54	NS
Treatment	14	138.46	9.89	97.13	1.87	S
Years x Treatment	14	0.26	0.02	0.19	1.87	NS
Error	56	5.70	0.102			
Total	89	145.33				

ANOVA – LXIII: Analysis of variance for effect of soil fertility management on total organic carbon in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.12	0.06	1.87	3.34	NS
Treatment	14	61.90	4.42	132.92	2.06	S
Error	28	0.93	0.03			
Total	44	62.95				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.14	0.07	1.69	3.34	NS
Treatment	14	59.12	4.22	101.97	2.06	S
Error	28	1.16	0.04			
Total	44	60.42				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.21	0.21	5.63	4.01	S
Replication	4	0.26	0.07	1.77	2.54	NS
Treatment	14	120.72	8.62	230.94	1.87	S
Years x Treatment	14	0.30	0.02	0.57	1.87	NS
Error	56	2.09	0.037			
Total	89	123.59				

ANOVA – LXIV: Analysis of variance for effect of soil fertility management on cation exchange capacity in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.10	0.05	0.09	3.34	NS
Treatment	14	81.21	5.80	10.02	2.06	S
Error	28	16.22	0.58			
Total	44	97.53				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.11	0.05	0.10	3.34	NS
Treatment	14	80.36	5.74	10.49	2.06	S
Error	28	15.32	0.55			
Total	44	95.78				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.09	0.09	0.16	4.01	NS
Replication	4	0.21	0.05	0.09	2.54	NS
Treatment	14	161.56	11.54	20.50	1.87	S
Years x Treatment	14	0.01	0.00	0.00	1.87	NS
Error	56	31.53	0.563			
Total	89	193.40				

ANOVA – LXV: Analysis of variance for effect of soil fertility management on available nitrogen in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	5.89	2.95	0.37	3.34	NS
Treatment	14	5466.86	390.49	48.64	2.06	S
Error	28	224.81	8.03			
Total	44	5697.56				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.80	0.90	0.12	3.34	NS
Treatment	14	5233.43	373.82	51.28	2.06	S
Error	28	204.11	7.29			
Total	44	5439.35				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	164.86	164.86	21.52	4.01	S
Replication	4	7.69	1.92	0.25	2.54	NS
Treatment	14	10669.55	762.11	99.50	1.87	S
Years x Treatment	14	30.75	2.20	0.29	1.87	NS
Error	56	428.92	7.659			
Total	89	11301.77				

ANOVA – LXVI: Analysis of variance for effect of soil fertility management on available phosphorus in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.10	0.05	0.95	3.34	NS
Treatment	14	357.68	25.55	508.84	2.06	S
Error	28	1.41	0.05			
Total	44	359.18				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	0.40	3.34	NS
Treatment	14	358.01	25.57	825.89	2.06	S
Error	28	0.87	0.03			
Total	44	358.90				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.31	0.31	7.72	4.01	S
Replication	4	0.12	0.03	0.74	2.54	NS
Treatment	14	715.59	51.11	1259.38	1.87	S
Years x Treatment	14	0.10	0.01	0.17	1.87	NS
Error	56	2.27	0.041			
Total	89	718.39				

ANOVA – LXVII: Analysis of variance for effect of soil fertility management on available potassium in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.99	1.00	0.64	3.34	NS
Treatment	14	1658.39	118.46	75.84	2.06	S
Error	28	43.74	1.56			
Total	44	1704.12				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	7.50	3.75	1.49	3.34	NS
Treatment	14	1447.22	103.37	40.94	2.06	S
Error	28	70.70	2.52			
Total	44	1525.42				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.29	0.29	0.14	4.01	NS
Replication	4	9.49	2.37	1.16	2.54	NS
Treatment	14	3039.20	217.09	106.23	1.87	S
Years x Treatment	14	66.42	4.74	2.32	1.87	S
Error	56	114.43	2.043			
Total	89	3229.84				

ANOVA – LXVIII: Analysis of variance for effect of soil fertility management on available sulphur in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.11	0.05	1.25	3.34	NS
Treatment	14	19.59	1.40	32.21	2.06	S
Error	28	1.22	0.04			
Total	44	20.91				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.05	0.02	0.49	3.34	NS
Treatment	14	19.80	1.41	28.63	2.06	S
Error	28	1.38	0.05			
Total	44	21.23				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.02	0.02	0.37	4.01	NS
Replication	4	0.16	0.04	0.85	2.54	NS
Treatment	14	39.38	2.81	60.60	1.87	S
Years x Treatment	14	0.00	0.00	0.01	1.87	NS
Error	56	2.60	0.046			
Total	89	42.16				

ANOVA – LXIX: Analysis of variance for effect of soil fertility management on exchangeable calcium in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.001	0.001	0.22	3.34	NS
Treatment	14	0.03	0.002	0.85	2.06	NS
Error	28	0.08	0.003			
Total	44	0.11				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.0002	0.0001	0.04	3.34	NS
Treatment	14	0.03	0.002	1.04	2.06	NS
Error	28	0.06	0.002			
Total	44	0.09				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.002	0.002	0.65	4.01	NS
Replication	4	0.001	0.0003	0.14	2.54	NS
Treatment	14	0.06	0.005	1.85	1.87	NS
Years x Treatment	14	0.001	0.00004	0.02	1.87	NS
Error	56	0.14	0.002			
Total	89	0.20				

ANOVA – LXX: Analysis of variance for effect of soil fertility management on available zinc in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.0003	0.0002	0.67	3.34	NS
Treatment	14	0.31	0.02	88.19	2.06	S
Error	28	0.01	0.0002			
Total	44	0.32				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.002	0.001	2.26	3.34	NS
Treatment	14	0.33	0.02	67.66	2.06	S
Error	28	0.01	0.0003			
Total	44	0.34				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	29.28	4.01	S
Replication	4	0.002	0.0005	1.59	2.54	NS
Treatment	14	0.63	0.05	151.86	1.87	S
Years x Treatment	14	0.003	0.0002	0.65	1.87	NS
Error	56	0.02	0.0003			
Total	89	0.66				

ANOVA – LXXI: Analysis of variance for effect of soil fertility management on available iron in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.04	1.02	1.47	3.34	NS
Treatment	14	4.56	0.33	0.47	2.06	NS
Error	28	19.41	0.69			
Total	44	26.01				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.80	0.90	1.28	3.34	NS
Treatment	14	3.89	0.28	0.39	2.06	NS
Error	28	19.75	0.71			
Total	44	25.45				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.10	0.10	0.15	4.01	NS
Replication	4	3.84	0.96	1.37	2.54	NS
Treatment	14	8.39	0.60	0.86	1.87	NS
Years x Treatment	14	0.06	0.00	0.01	1.87	NS
Error	56	39.16	0.699			
Total	89	51.56				

ANOVA – LXXII: Analysis of variance for effect of soil fertility management on available manganese in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.67	0.83	1.01	3.34	NS
Treatment	14	4.77	0.34	0.41	2.06	NS
Error	28	23.24	0.83			
Total	44	29.68				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.63	0.81	0.98	3.34	NS
Treatment	14	4.69	0.33	0.40	2.06	NS
Error	28	23.23	0.83			
Total	44	29.54				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.03	0.03	0.04	4.01	NS
Replication	4	3.30	0.82	0.99	2.54	NS
Treatment	14	9.45	0.68	0.81	1.87	NS
Years x Treatment	14	0.00	0.0003	0.0003	1.87	NS
Error	56	46.47	0.830			
Total	89	59.25				

ANOVA – LXXIII: Analysis of variance for effect of soil fertility management on available copper in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.11	0.05	1.36	3.34	NS
Treatment	14	0.37	0.03	0.67	2.06	NS
Error	28	1.11	0.04			
Total	44	1.59				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.07	0.04	0.93	3.34	NS
Treatment	14	0.39	0.03	0.70	2.06	NS
Error	28	1.12	0.04			
Total	44	1.59				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.02	0.02	0.51	4.01	NS
Replication	4	0.18	0.05	1.14	2.54	NS
Treatment	14	0.76	0.05	1.37	1.87	NS
Years x Treatment	14	0.00	0.00	0.00	1.87	NS
Error	56	2.23	0.040			
Total	89	3.20				

ANOVA – LXXIV: Analysis of variance for effect of soil fertility management on exchangeable acidity in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	0.37	3.34	NS
Treatment	14	20.41	1.46	111.93	2.06	S
Error	28	0.36	0.01			
Total	44	20.79				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	0.61	3.34	NS
Treatment	14	22.74	1.62	82.82	2.06	S
Error	28	0.55	0.02			
Total	44	23.32				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.27	0.27	16.75	4.01	S
Replication	4	0.03	0.01	0.52	2.54	NS
Treatment	14	43.10	3.08	188.63	1.87	S
Years x Treatment	14	0.06	0.004	0.24	1.87	NS
Error	56	0.91	0.016			
Total	89	44.38				

ANOVA – LXXV: Analysis of variance for effect of soil fertility management on exchangeable Al in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.03	0.02	0.30	3.34	NS
Treatment	14	22.16	1.58	27.81	2.06	S
Error	28	1.59	0.06			
Total	44	23.79				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.14	0.07	1.82	3.34	NS
Treatment	14	20.31	1.45	39.01	2.06	S
Error	28	1.04	0.44			
Total	44	21.49				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.43	0.43	9.07	4.01	S
Replication	4	0.17	0.04	0.90	2.54	NS
Treatment	14	42.43	3.03	64.39	1.87	S
Years x Treatment	14	0.05	0.004	0.08	1.87	NS
Error	56	2.64	0.05			
Total	89	45.71				

ANOVA – LXXVI: Analysis of variance for effect of soil fertility management on total potential acidity in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.45	0.22	0.72	3.34	NS
Treatment	14	35.34	2.52	8.08	2.06	S
Error	28	8.75	0.31			
Total	44	44.54				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.10	0.05	0.12	3.34	NS
Treatment	14	35.77	2.56	5.87	2.06	S
Error	28	12.19	0.44			
Total	44	48.07				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.08	0.08	0.21	4.01	NS
Replication	4	0.55	0.14	0.37	2.54	NS
Treatment	14	71.11	5.08	13.58	1.87	S
Years x Treatment	14	0.004	0.0003	0.0007	1.87	NS
Error	56	20.94	0.374			
Total	89	92.68				

ANOVA – LXXVII: Analysis of variance for effect of soil fertility management on pH – dependent acidity in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.49	0.24	1.02	3.34	NS
Treatment	14	5.59	0.40	1.69	2.06	NS
Error	28	6.63	0.24			
Total	44	12.70				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.04	0.02	0.04	3.34	NS
Treatment	14	4.68	0.33	0.62	2.06	NS
Error	28	15.19	0.54			
Total	44	19.92				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	0.02	4.01	NS
Replication	4	0.53	0.13	0.34	2.54	NS
Treatment	14	10.13	0.72	1.86	1.87	NS
Years x Treatment	14	0.14	0.01	0.02	1.87	NS
Error	56	21.82	039			
Total	89	32.63				

ANOVA – LXXVIII: Analysis of variance for effect of soil fertility management on soil microbial biomass carbon in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	220.27	110.14	1.02	3.34	NS
Treatment	14	283185.56	20227.54	188.18	2.06	S
Error	28	3009.75	107.49			
Total	44	286415.59				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	64.13	32.07	0.31	3.34	NS
Treatment	14	276671.32	19762.24	189.35	2.06	S
Error	28	2922.38	104.37			
Total	44	279657.83				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	150.18	150.18	1.42	4.01	NS
Replication	4	284.41	71.10	0.67	2.54	NS
Treatment	14	559766.36	39983.31	377.45	1.87	S
Years x Treatment	14	90.53	6.47	0.06	1.87	NS
Error	56	5932.13	105.931			
Total	89	566223.61				

ANOVA – LXXIX: Analysis of variance for effect of soil fertility management on soil basal respiration in direct seeded rice

ANOVA Table of first year 2021						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00005	0.00003	0.01	3.34	NS
Treatment	14	53.36	3.81	945.45	2.06	S
Error	28	0.11	0.004			
Total	44	53.47				

ANOVA Table of second year 2022						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.0003	0.0002	0.03	3.34	NS
Treatment	14	53.66	3.83	793.39	2.06	S
Error	28	0.14	0.005			
Total	44	53.79				

ANOVA Table of Pooled						
Source of Variance	**Degree of Freedom**	**Sum of Square**	**Mean Sum of Square**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.06	0.06	12.58	4.01	S
Replication	4	0.00	0.00	0.02	2.54	NS
Treatment	14	107.01	7.64	1725.02	1.87	S
Years x Treatment	14	0.01	0.0005	0.11	1.87	NS
Error	56	0.25	0.004			
Total	89	107.32				

Appendix – B

(A)	FIXED COST			
Sl.no	Particulars	Input/Quantity	Rate (₹ unit^{-1})	Cost (₹ ha^{-1})
1.	**Field preparation**			
	a. Ploughing	1 man/day	1000	1000
	b. Harrowing	1 man/day	1000	1000
	c. Bed preparation and sowing	6 man/day	400/man/day	2400
2.	**Interculture operations**			
	Thinning, hand weeding and earthing up	10 man/day	400/man/day	4000
3.	**FYM**			
	Labour charges	4 man/day	400/man/day	1600
4.	**Liming**			
	Labour charges	2 man/day	400/man day	800
5.	**Plant protection**			
	a. Labour charges	10 man/day	400/man/day	4000
	b. Insecticide			
	Chloropyriphos	4 litres	550/500ml	4400
	Malathion	1 litre	819/litre	819
6.	**Harvesting, threshing and winnowing**	15 man/day	400/man/day	6000
7.	**Miscellaneous**	-	-	3000
8.	**Rice seed**	80	25	2000
	Total			**31019**

(B)	COST OF VARIABLE INPUTS ha^{-1}			
Sl.no.	Inputs	Unit/Qty (kg ha^{-1})	Rate (₹ unit^{-1})	Cost (₹ ha^{-1})
T_1	**Control**	-	-	-
T_2	**100% NPK**			
	N & P (DAP)	130.43	25	3260.75
	N (urea)	166.04	6	1062.65
	K (MOP)	66.67	20	1306.73
	TOTAL			**5630.13**
T_3	**50% NPK**			
	N & P (DAP)	65.22	25	1630.38
	N (urea)	83.02	6	531.33
	K (MOP)	33.34	20	653.37
	TOTAL			**2815.07**

T_4	**SSNM (109:30:46)**			
	N & P (DAP)	109.00	25	2725.00
	N (urea)	30.00	6	192.00
	K (MOP)	46.00	20	901.60
TOTAL				**3818.60**
T_5	**100% NPK + Zn**			
	N & P (DAP)	130.43	25	3260.75
	N (urea)	166.04	6	1062.65
	K (MOP)	66.67	20	1306.73
	Zn (Zn SO4. 7H2O)	47.60	58	2760.80
TOTAL				**8390.93**
T_6	**100% NPK +S**			
	N & P (DAP)	130.43	25	3260.75
	N (urea)	166.04	6	1062.65
	K (MOP)	66.67	20	1306.73
	S (CaSO4)	107.53	15	1612.95
TOTAL				**7243.08**
T_7	**100% NPK+ Zn +S**			
	N & P (DAP)	130.43	25	3260.75
	N (urea)	166.04	6	1062.65
	K (MOP)	66.67	20	1306.73
	Zn (Zn SO4. 7H2O)	47.60	58	2760.80
	S (CaSO4)	81.83	15	1227.45
TOTAL				**9618.38**
T_8	**100% NPK+ Zn +S +FYM @5 t ha^{-1}**			
	N & P (DAP)	130.43	25	3260.75
	N (urea)	166.04	6	1062.65
	K (MOP)	66.67	20	1306.73
	Zn (Zn SO4. 7H2O)	47.60	58	2760.80
	S (CaSO4)	81.83	15	1227.45
	FYM	5000	2	10000.00
TOTAL				**19618.00**
T_9	**100% NPK + Liming @LR**			
	N & P (DAP)	130.43	25	3260.75
	N (urea)	166.04	6	1062.65
	K (MOP)	66.67	20	1306.73
	Lime	562.27	10	5622.70
TOTAL				**11252.83**

T_{10}	**50% NPK + Azospirillum**			
	N & P (DAP)	65.22	25	1630.38
	N (Urea)	83.02	6	531.33
	K (MOP)	33.34	20	653.37
	Azospirillum	0.6	40	24.00
TOTAL				**2839.08**
T_{11}	**50% NPK + 50% N -FYM**			
	N & P (DAP)	65.22	25	1630.38
	N (Urea)	83.02	6	531.33
	K (MOP)	33.34	20	653.37
	FYM	10000.00	2	20000.00
TOTAL				**22815.08**
T_{12}	**50% NPK + 50% N – VC**			
	N & P (DAP)	65.22	25	1630.38
	N (Urea)	83.02	6	531.33
	K (MOP)	33.34	20	653.37
	VC	1666.66	25	41666.50
TOTAL				**44481.58**
T_{13}	**50% NPK+25% N FYM+ 25% N- VC**			
	N & P (DAP)	65.22	25	1630.38
	N (Urea)	83.02	6	531.33
	K (MOP)	33.34	20	653.37
	FYM	5000.00	2	10000.00
	VC	833.33	25	20833.25
TOTAL				**53648.33**
T_{14}	**FYM @ 10t ha^{-1}**			
	FYM	10.00	2	20000.00
TOTAL				**20000.00**
T_{15}	**FYM @ 10t ha^{-1} + Liming @ LR**			
	FYM	10.00	2	20000.00
	Lime	562.27	10	5622.70
TOTAL				**25622.70**